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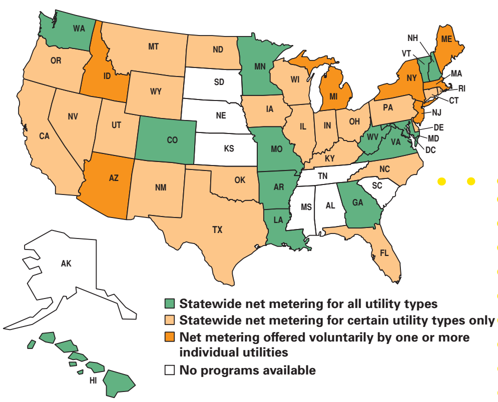

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Photo by Shawn Schreiner

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from us *to you*

Unstoppable

The news is good: The U.S. Energy Information Administration announced in early October that electricity production from renewable energy in the United States was up 32% from the previous year. And, for the first time in U.S. history, RE-generated electricity topped 11% of the national supply. Much of this has been driven by government financial incentives and regulatory requirements aimed specifically at increasing the use of RE.

Seeing RE gain momentum against other technologies is indeed reason to celebrate. But in an economy that has been reeling from significant job losses in other sectors, it is the creation of new RE jobs that strikes a chord with politicians and economists. A September 2008 study commissioned by the Solar Energy Research and Education Foundation projected that extending the highly successful solar investment tax credits (ITCs) for eight additional years beyond their December 2008 expiration would create 276,000 new, permanent jobs in the RE industry by 2016. For frame of reference, the U.S. Department of Labor estimates that there are only 136,000 jobs in oil and gas extraction.

And now we have been handed those very tax credits and more to further increase RE's impetus—thanks to the tireless efforts of the Solar Energy Industries Association, the American Wind Energy Association, dozens of other organizations, and millions of RE enthusiasts like you. In the final hours of the last Congressional session before the election, an eight-year extension of RE tax credits was passed and signed into law—tacked onto the $700 billion Wall Street bailout. The extension includes:

- Eight more years for the 30% ITC for residential and commercial solar installations
- Elimination of the tax-credit cap for residential solar-electric installations
- A new eight-year 30% ITC for residential and commercial small wind installations, with a $4,000 cap
- A one-year extension of the wind production tax credit
- Addition of a tax credit of up to $7,500 for plug-in hybrid electric vehicles
- A one-year extension of energy-efficiency ITCs for new and existing residences
- Provisions allowing utilities to benefit from the credits
- Provisions allowing Alternative Minimum Tax filers to take the tax credit
- Authorization of $800 million for clean energy bonds for RE generating facilities

The majority of RE legislation-watchers felt the extension of the tax credits would eventually be approved, but there was a lot of uncertainty as to when that might happen. While many people bemoan the financial industry bailout that carried our industry's Energy Improvement and Extension Act along with it, we are pleased to have been included within this other seemingly unstoppable legislation.

These victories certainly ensure an RE future, but that does not mean we can rest on our laurels. The immediacy of a looming environmental crisis requires continued effort to speed up the inevitable switch to renewable energy. So pat yourself on the back for the fine, successful efforts, and now let's all get back to work accelerating the unstoppable clean, safe, and just energy future.

—Michael Welch, for the *Home Power* crew

Think About It...

"Every idea whose time has come began as an idea ahead of its time."

—Jane Holl Lute, United Nations Assistant Secretary-General for Peacebuilding Support

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Utility Adjustments

I hear that reducing individual energy consumption can make a difference in the country's carbon footprint. My question is, do the utility companies have software or systems in place to produce only what is needed, or when I reduce my usage, does the net extra energy just get wasted? If the coal plants and other generators are producing a predetermined amount of energy, conservation won't help much. Any insight into how the utilities manage the grid might go a long way toward helping consumers conserve energy.

Brian Jarvis • Brookline, Massachusetts


Zsolt Biczó / iStockphoto

Utilities have several types of power plants. Some are designed to run at or near maximum capacity at all times because that is the way they run best, and they may be slow to react to adjusting their output. Some produce energy so cheaply (like large hydro-electric plants) that the utilities want to run them at capacity as much as they can. Others, such as natural gas turbines and reciprocating engines, are designed to come online or ramp up production very quickly when needed.

That aside, utilities have gotten pretty good at predicting what the system-wide demand will be for any given time, based on years of history and what recent demand has been. Usually, only minor adjustments need to be made. But when there are big, sudden drops in demand, utilities take immediate steps to shut down some of their power plants' generation.

All utilities are connected together in a grid so that local changes in demand are absorbed fairly well. Also, reduction in household consumption typically happens slowly, over time.

Finally, even though many of us are finding ways to reduce consumption, the overall trend system-wide (in nearly all markets) is still an increase in demand, as population increases and business needs go up in our electronic world.

Michael Welch • *Home Power*

I was in a utility control room once when a 400-megawatt plant tripped and went off-line. The lights hardly flickered, as grid operators immediately dispatched their "spinning reserve," the backup power stations that are kept ready for just this purpose.

The electric grid is one of the nation's most marvelous machines. But it has one enormous downside—the production of electricity is responsible for nearly 40% of U.S. carbon emissions. Today, every 1,000 kilowatt-hours sold in this country comes "bundled" with 1,400 pounds of carbon dioxide, some of which will still be in the atmosphere 500 years from now.

Electric utilities are in the bull's-eye of climate policy, and many are beginning to examine how they can reduce emissions. On the menu: improving the efficiency of existing power plants; retiring older fossil-fueled plants; adding new, efficient natural-gas plants; purchasing carbon-free renewable energy; building new nuclear plants; and changing the order in which power plants are operated or "dispatched."

Some utilities are shrinking their carbon footprints. For example, in Colorado, Xcel Energy has lowered its carbon emissions per megawatt-hour by nearly 20%, and has set ambitious targets for further reductions in the years ahead.

There are two caveats, and they are big ones. First, reductions in emissions intensity are not sufficient to stop global warming; we need real reductions and large ones at that. Due to increased population and economic growth, it will be difficult for Xcel (and many other utilities) to reduce their total emissions. Second, since coal provides more than half of U.S. electricity and accounts for 80% of the sector's emissions, if we don't quickly develop and deploy much cleaner coal stations, or replace them with renewables, climate change is likely to accelerate.

Five to eight percent of all electricity is lost in the transmission system on its way to your home, so there's a new focus on reducing line losses in the distribution system. Improved transformers are available now, and superconductivity holds promise for the future.

At the personal level, a typical family produces enough greenhouse gases each year to fill two blimps. Half of this comes from burning gasoline, but most of the rest is due to electricity consumption. Cutting your personal electricity use through conservation and efficiency, and by using renewables, can save you money and lead to large decreases in your carbon footprint. For example, a solar efficiency retrofit of my home will keep 300,000 pounds of carbon dioxide out of the atmosphere over the next 20 years.

Randy Udall • Independent Energy Analyst

"Every 1,000 kilowatt-hours sold in this country comes 'bundled' with 1,400 pounds of carbon dioxide."


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Commercial PV without Net Metering

Courtesy David Calligeros

My company is moving into a new factory (the four-story white building in the middle of the photo) in Brooklyn, New York. We run a machine shop, and do polishing, metal finishing, and casting. We are seriously considering installing a large PV array (perhaps 35 kW) among other RE and efficiency measures.

New York has no net metering incentives for commercial customers, so I'm left with the prospect of my weekend production (two-sevenths of total production) potentially getting wasted. There are some processes I can move to the weekends, but basically we operate on weekdays. Can you think of any clever ways of storing the energy? So far I've considered compressing air and storing it in a tank, and pumping water to a high storage tank and running a microturbine from it on Monday mornings. Is this crazy?

David Calligeros • New York, New York

What a tough place to do RE business! New York City has its own electrical code and very protective permitting. But folks are dealing with the hurdles and putting in RE systems anyway.

Any time energy is transferred, there is a loss. Compressing air with PV-generated electricity will be expensive and inefficient. Pumped water storage has lots of problems, including efficiency, and there's the fact that you'll need a hydro-electric system. One option is to negotiate a power purchase agreement with your utility for the extra energy produced. If your state requires utilities to have a minimum of RE-made electricity, then the utility may be willing to give you a good price. Or, they may merely pay you for the electricity's "avoided cost," which is usually based on the cheapest energy source in the utility's system—often hydropower, which may be valued at only a few cents per kWh.

I have a couple of ideas for you to store weekend-generated energy for later use. In the winter, when heating loads are significant, a large water storage tank could be heated with the surplus energy and then used to augment the existing heating system. In summer, cooling loads are significant. Some companies actually install chiller systems that freeze water at night and on weekends (when utility electricity is cheaper) to help with cooling. Maybe excess PV output could be used to perform a similar function. Using a heat pump would make the most of your PV-generated kilowatt-hours.

The viability of these options depends on whether the existing heating and cooling infrastructure could be easily modified to incorporate such input. Portions of the spring and fall seasons when neither heating nor cooling needs are significant might be times when PV output needs a different job.

Here's a completely different idea: There are lots of apartment buildings in Bushwick, and they use energy seven days a week. Maybe you could arrange to provide your excess electricity to an adjacent apartment building or business that has weekend needs. Better check on NYC laws about providing electricity to others—you might not be allowed to charge for it. But if you donated it to a low-income housing unit or a nonprofit, there might be some way to get a tax deduction for such a charitable contribution. Just brainstorming here, but maybe it will trigger more ideas that bring a viable solution.

E. H. Roy, Nexgen Energy Systems •
Stewartstown, New Hampshire

"If your state requires utilities to have a minimum of RE-made electricity, then the utility may be willing to give you a good price."

Geothermal Heating

I am considering having a geothermal heat pump installed at my home. The home is 100 years old and has a very unique feature—a hand-dug well in the basement. The well is 3 feet in diameter and 21 feet deep, and holds about 1,000 gallons of water. My idea is to put a closed loop of copper or PEX piping into the well, using it as the heat source.

I have received conflicting advice—one contractor says that the well is too small and a civil engineer says it should be OK. The engineer's reasoning is that the heat will dissipate not only into the well water, but the entire aquifer. Do you have any advice or experience regarding this type of installation?

David Hershey • Elizabethtown, Pennsylvania

Unfortunately, this idea is unlikely to work—the amount of pipe you can put into the area you describe would probably be insufficient to meet the home's heating or cooling load. In northern climates, the geothermal heat pump would quickly remove the heat from this small surface area and freeze the water around the pipes. In southern climates, the water around the pipes would get too hot and the heat pump would not cool the house. Even if the well you describe flowed like a river, you still wouldn't have enough pipe surface area to move the heat in a closed-loop system.

Geothermal heat-pump manufacturers have developed at least three time-tested methods—vertical, horizontal, and lake loops—for closed-loop ground heat exchangers. Heat-pump system designers should always start with an accurate heat loss/heat gain calculation for the building's requirements. They can use this figure, measured in Btu (British thermal units), to determine the amount of pipe needed for each type of ground loop. The amount of pipe is a function of the loop choice, due mostly to the differences in efficiency of heat transfer.

Lake loops can be the easiest to install and require the least amount of pipe. But you need at least a half-acre lake with a minimum depth of 8 feet. Horizontal ground loops take more pipe and require more land area. Vertical ground loops are the most compact heat exchangers. They are often installed under the footprint of the house or driveway, as long as the manifold where the pipes come together is accessible. These loops are typically installed in 4- to 6-inch-diameter bores at least 200 feet deep. These loops are often the most expensive because of drilling costs.

Although it costs more to install geothermal heat pumps, the difference in the cost is usually for the ground heat exchanger, which, if properly installed, will last the life of the building.

Charles Davis, The Earth Comfort Company • Savannah, Georgia

Courtesy www.waterfurnace.com

From left to right: A lake loop in a pond, a horizontal loop in filled-in trenches, and a vertical loop in bored wells.

"Heat-pump manufacturers have developed at least three time-tested methods—vertical, horizontal, and lake loops—for closed-loop ground heat exchangers."

Salvaging Prius Batteries

There are some wrecked Prius hybrids at the local salvage yard, and I can get their battery packs cheap. Can I put two or three of these together to power my pure-electric conversion?

John McElhattan • Fresno, California


Courtesy www.toyota.com

Bundling these battery banks is not recommended, for a few reasons. The battery pack in the Prius (or any of the other hybrids) does not have the capacity for much range by itself. Even at low speeds in pure-electric mode, the Prius has only about 2 miles of range before the gas engine starts up to recharge the pack. So you would need a *lot* of packs to get any decent range.

Also, these batteries are not intended to be discharged very deeply. They were specifically designed to work with a gas engine frequently topping them off. In a pure electric vehicle, you need batteries that can tolerate being deeply discharged before getting recharged.

You would also need the battery management system that is part of the Prius's computer brain. While these battery packs are perfectly safe in the Prius, if they are installed or managed improperly, they can catch fire, which some tinkerers have already had the misfortune to experience.

Prius batteries work great in the original vehicle's system. There are other batteries that are better suited to a pure-electric conversion.

Mike Brown & Shari Prange • *Home Power* Transportation Editors

Horse Power

A local draft horseman has asked me whether a farmer, using what is at hand, could design and build a horse sweep capable of turning a generator and thereby producing electricity for his household and farm. Have you heard of such a thing?

Ted Smith • Quincy, Illinois

The short answer is: Yes—it is possible to produce electricity using draft animals. Realistically, however, it would probably only make sense if you already own a horse and are interested in combining a regular exercise regimen (for both the animal and the owner, as it turns out) with generating a modest amount of electricity.

The amount of power a horse can generate on a sustainable basis is—you guessed it—one horsepower (746 watts). For various reasons, both practical and humane, we probably don't want to use this system for more than one or two hours per day. At this rate, after taking into account losses in the entire system (mechanical and electrical), we might expect to generate 500 to 1,000 watt-hours (0.5 to 1 kWh) per day.

Now let's deal with the fine print—there are some energy costs to horse power. First of all, horses need to be fed. The best possible scenario is one in which the animal collects all of its food with no help from the owner. That's unlikely, so the energy it took to grow the food and feed the horse needs to be subtracted from the generated output. Next, horses produce a lot of manure—figure on 100 pounds per day as a good start. Unfortunately, while a horse might be able to eat on its own, it does a pretty poor job of cleaning up after itself. And the horse will be depositing its "exhaust products" in a very limited area when generating electricity (unlike the case when it is working in a field, for example). So the task of cleaning up falls squarely on the owner—along with harnessing and unharnessing the horse each day.

So this concept, while possible, will demand a significant amount of work from both the horse and the owner. When all is said and done, the owner may end up consuming and expending more energy (lights, water pumping, hauling of manure, etc.) than is supplied by the horse! An argument can be made either way, but personally, I say, "Neigh!"

Dominic Crea • Institute for Sustainable Energy & Education

"Even at low speeds in pure-electric mode, the Prius has only about 2 miles of range before the gas engine starts up to recharge the pack."


Trojan
L16RE-B
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T105-RE
RE SERIES

Act Locally

Courtesy westarborstudios

Michael Welch and Joe Schwartz wrote interestingly related articles in *HP126* about carbon offsets and whether batteries are needed for RE systems. When we reduce our burning of fossil fuels, carbon and other emissions go down. Examples include running our vehicles and yard tools less (using less fuel), and adjusting our thermostats (using less oil, LP, or natural gas in our furnaces). These are situations in which we know absolutely that we are polluting less.

But it's not as certain when we conserve with electricity. My household cut its annual electricity usage by one-third from 1999 to 2006. Did my Kentucky electric utility burn less coal because I used less? Maybe not. The utility actually added new power plants in that time period, so emissions went up. Local usage and demand increased far more than ours went down. This is common. Nowadays, most utilities with occasionally underused generation capacity also sell unsold electricity to other utilities. Once a power plant is built, it's likely used as much as possible, regardless of who gets the electricity. People near the power plant get the pollution, regardless of how much energy they use (or don't use).

So we cannot ascertain that emissions go down if we individually use less conventional electricity. Only our responsibility goes down. This distinction is important in my region since the closest city (Cincinnati) is the tenth-most particulate-polluted city in the United States. If we really want less pollution locally, we need to burn less coal. Offsets don't achieve that, even if they encourage local grid-tied solar electricity. This is because Cincinnati's electric utility primarily uses natural gas generators to meet peak afternoon summertime electric demand—when PV systems put the most electricity on the grid. Large coal-fired base-load power plants run constantly, mostly unaffected by peak loads or PV energy. Grid-tied PV systems in my region reduce more demand for natural gas than coal.

Natural gas generators can be powered down and back up in as little as 30 minutes, while large coal-fired power plants need up to 10 hours to power down and back up. Since all combustion generators emit more pollution per kWh when they are cycled down, and since the EPA fines utilities when emissions exceed allowable levels per power plant output, don't expect local utilities to cycle down power plants when a few consumers lower their loads slightly for short durations. You need large amounts of longer-term load reduction to shut down coal power plants!

When Joe Schwartz wrote that batteries aren't necessary for a PV system, he meant that you can avoid the hassles and inefficiencies of batteries by installing a cheaper, batteryless grid-tied PV system. But that means using the local electric grid for backup. In my region, every time a cloud shades a grid-tied PV array or electricity is used at night, fossil-fueled generators supply the electricity. Fossil-fueled power plants have carbon emissions, but batteries do not. If you lower demand for natural gas during the summer afternoon but need coal-fired electricity at night or during winter, you're not achieving full carbon offset for your net-metered solar kWh, because coal-fired kilowatt-hours have 80% more carbon emissions than natural gas kWh. If you just want less responsibility for emissions generally, use and demand less fossil fuel energy. If you want lower emissions locally, reduce fossil fuel burning locally. Even if you want to absorb carbon dioxide with trees, plant locally. When you run out of reductions to implement at your own house or business, look elsewhere in your community. There's probably a gold mine of reduction opportunities close by. Think globally, but act locally and verify.

John F. Robbins • Morning View, Kentucky

"You need large amounts of longer-term load reduction to shut down coal power plants!"

Map Mistake

Thanks to everyone who took the time to write us about "PV vs. Solar Water Heating—Simple Solar Payback," which appeared in *HP127*. We expected some feedback from the article and were rewarded with a variety of comments. Many letters gave us information about individual experiences with one or both types of systems.

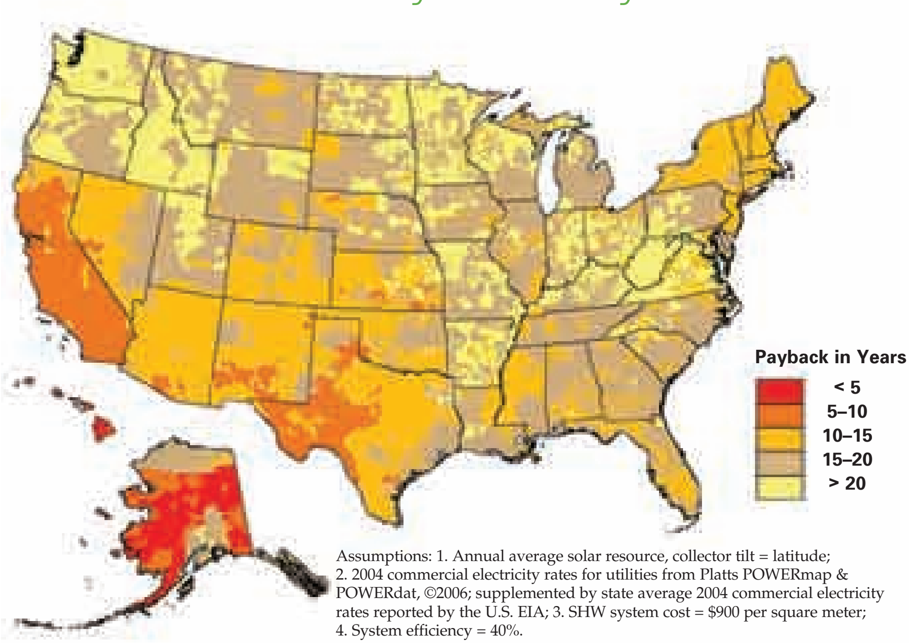
It was impossible in the short article to address all of the possible payback scenarios: There are countless circumstances where either type of solar energy system will offer quicker or slower returns on investment. SHW systems offsetting a cheaper source of energy like natural gas will lengthen the payback, while displacing a more expensive fuel like propane could shorten it. Other considerations, such as owner-installed or -built systems were too complex to quantify in this simple payback analysis.

The article used data from three sources: the National Renewable Energy Laboratory (its published payback comparison maps were only for electricity); the Solar Rating and Certification Corporation (SHW system output); and the NREL-sponsored PVWatts calculator (PV system output). We picked Richmond, Virginia, for the comparisons—a city that we thought was about average for solar irradiance (4.8 kWh/square meter/day) and winter climate (4,000 heating degree days), and had SRCC data. The rest was number crunching and organizing the data.

Many readers questioned the SHW map and key on page 43, which indicated surprising payback times. Here's the correct map with the correct key. As you can see, the predicted payback in the entire United States is more optimistic and more in line with many folks' expectations, and with the text and tables in the article.

Chuck Marken • *Home Power* Solar Thermal Editor

Solar Hot Water System Payback



Assumptions: 1. Annual average solar resource, collector tilt = latitude; 2. 2004 commercial electricity rates for utilities from Platts POWERmap & POWERdat, ©2006; supplemented by state average 2004 commercial electricity rates reported by the U.S. EIA; 3. SHW system cost = $900 per square meter; 4. System efficiency = 40%.

Across the Pond

I want to congratulate you on producing a very interesting magazine. The topics you write about are exactly what I want to do here in the United Kingdom. I want to run my house on clean energy and not rely on the electric or gas companies to supply my heating and lighting. This is also important since the cost of fossil fuel is rising. The United States has a very bad reputation across the world when it comes to burning fuel, but after reading your magazine, I realize that people in your country are pioneers in the field of getting free energy from the sun and the wind. I would like to follow suit in the U.K.

The U.K. has 80% of Europe's wind, and we should be using it and other renewable resources. I hope your magazine can encourage thousands of British people to turn toward renewables, as you have with me.

Michael Mitchell • Leeds, West Yorkshire, England

"The U.K. has 80% of Europe's wind, and we should be using it and other renewable resources."

Added Efficiency

In your article "PV vs. Solar Water Heating" (*HP127*), the "Efficiency Pays" sidebar is missing one major detail. The discussion of compact fluorescent lighting does not consider the heating load on an air-conditioning system. If you take one 60-watt compact fluorescent bulb and leave it on for 24 hours, you can still grab and hold onto it comfortably. Try that with a 60 W incandescent, and you will come back with serious burns! This extra heat could be seen as an advantage in winter, but it's better to be able to control your heaters thermostatically, and use lighting devices that give you what you want without extra heat.

Darin Harp • Paducah, Kentucky

Courtesy Ellen Van

Super-Insulated Tank

Using a tank-style water heater is kind of like leaving your car running 24/7 in case you need to run to the grocery store on short notice. I have a functioning conventional tank water heater and chose not to go with a tankless unit, but was still worried about my tank's energy use. Instead of the expense and complication of replacing it, I wanted to improve its performance.

First, I installed a simple $30 timer that turns on the heater for an hour in the morning, just before I get up, and again for an hour before evening showers. My cravings for improving it even more kept pestering me, and on one boring Sunday afternoon, I started a water heater insulation project. Perhaps that sounds simple—just go to the hardware store and get a water-heater blanket specially designed for that purpose. I wanted better results, so I got myself some high R-value blue insulation "boards" (extruded polystyrene sheets). I built a closet around the heater and left as much space as possible between the heater and the blue boards. I filled up the space left between the heater and the boards with loose insulation material. (This insulation method can only be used for an electric heater; a gas heater needs air supply and exhaust, so it's not as easy to insulate.)

The timer is now set to only 30 minutes twice a day, and I always (24/7) have a hot shower when I need one. I also have energy-efficient lighting, well-insulated water pipes, R-57 roof insulation, corn-biomass heating, and many other efficiency strategies, so my total energy bill for the month of August was $41. Not bad for an all-electric house!

Ellen Van • West Chester, Pennsylvania

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GPS monitoring station at Cape Roberts, Antarctica operates year-round with solar power and a large bank of Deka Solar Gel Batteries. Photo Courtesy of UNAVCO

Desert Orientation

An Energy-Wise Oasis

by Kelly Davidson
photos by Pat Scheibel

All Tom and Robbin Houchen wanted was an unobstructed tract of land for launching and landing their ultralights. What they found was an opportunity for energy independence on 40 sun-drenched and wind-swept acres.

In 1994, when there was still affordable acreage to be had, Tom and Robbin Houchen teamed up with Tom's brother, Michael Houchen, to buy 80 acres in the southwestern part of Kern County, California. They divided the land, with Tom and Robbin on 40 acres, and Michael on the other 40.

"We didn't have grand plans at first. We really just wanted space to fly our ultralights," Tom admits. "We took our time figuring out how to make the land work for us."

Tom and Robbin originally dismissed the idea of living on the land because the two-hour drive to Tom's office was too far for a daily commute. But they later reconsidered when Tom's circumstances changed, allowing him to work from home as computer programmer.

Tom, a self-professed tinkerer who first experimented with solar water heating at a previous home, had been keeping tabs on energy policy and advances in RE technologies since the late 1980s. Like so many Californians coping with rising energy costs, he hoped that the price of renewable energy components would drop and make self-generation more feasible for the average homeowner.

"Only when the state started seriously talking about rebates and other incentives did I begin to see the real potential for our land," Tom, 61, says. "The wind whips over the mountains, and the sun is fierce. We had an ideal spot for renewable energy. It was just a matter of time, money, and the state following through with its plans."

Prefab Construction

The Houchens chose to save time and money by erecting a prefabricated modular home rather than building a custom home on the site. "We had some initial reservations about a modular approach," Tom says. "But after visiting the manufacturing facility, we were won over by the quality and sturdiness of the steel-frame design. They're really built to last." The fact that the overall process is believed to use less energy and produce less waste than a traditional site-built home tipped the scale even further, he adds.

The ground-mounted array provides greater accessibility for cleaning and maximizes airflow around the modules.

The Bergey Excel-S wind turbine takes advantage of the excellent wind resource at the site.

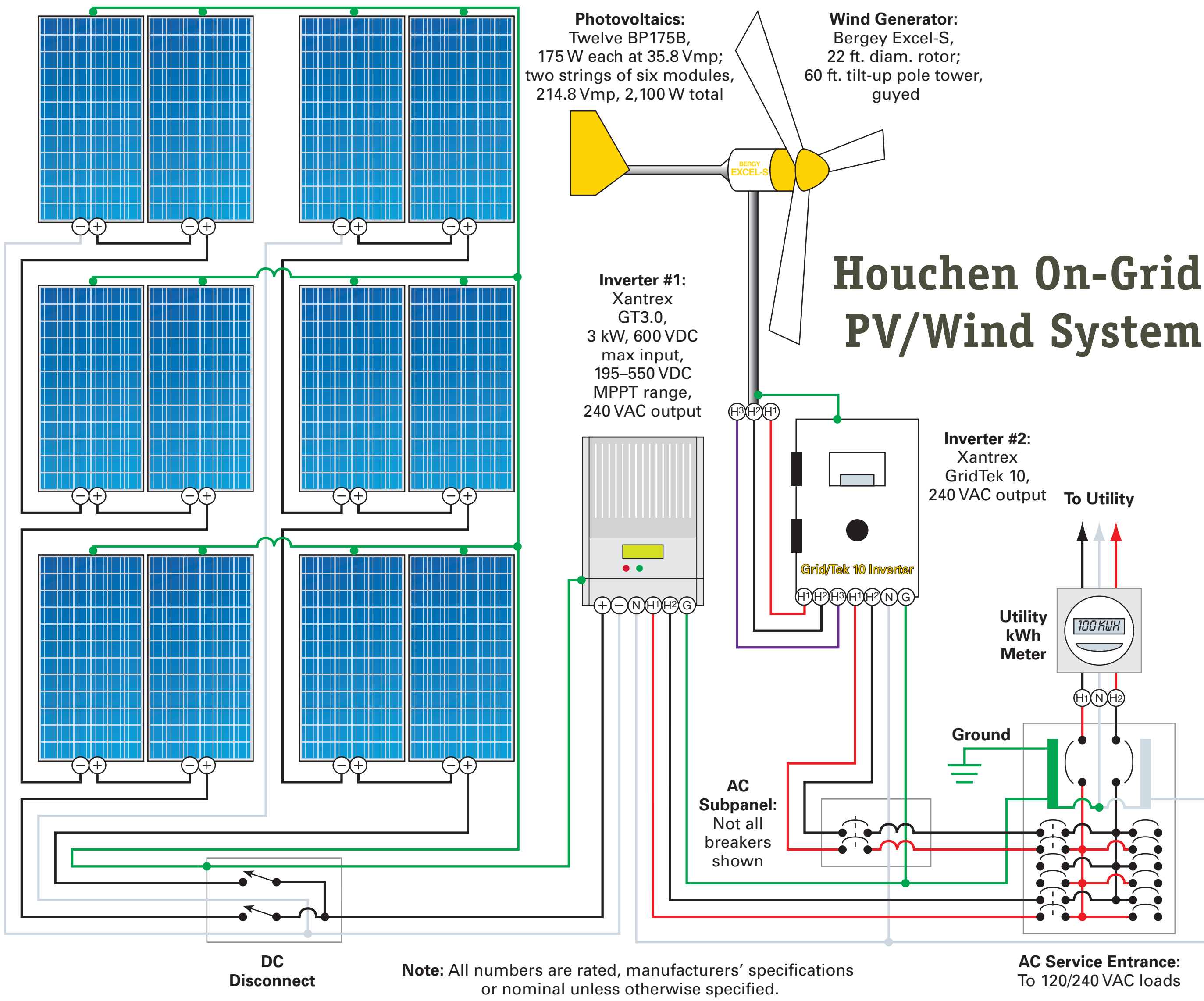
Tom and Robbin settled on a triple-wide design for a one-story, 2,500-square-foot house, complete with three bedrooms and two bathrooms. For added protection from the desert temperature extremes, they doubled the fiberglass insulation in the walls and ceilings, and upgraded to argon gas-filled, double-pane windows. And, to minimize their electrical loads, they chose to use propane for heating water and cooking.

Tom considered wiring the house for DC loads as well as the standard AC loads to allow greater flexibility when, or if, the time came to install an RE system. He ultimately dropped the idea because the additional circuits and larger diameter wire necessary would have cost too much—plus, the selection of DC appliances proved to be limited. Instead, he trusted that newer inverters on the market would be more dependable and offer acceptable efficiency losses.

Wind Worthy

By 2000, the house was finished, and Tom and Robbin had turned their attention to saving and planning for a wind turbine, since the site's potential for wind power was undeniable. Several wind farms in the county—including California's second largest at Tehachapi Pass—were already taking advantage of the strong class 5 and 6 winds blowing across the valley.

Initially, Tom discounted the idea of a wind system because of the high cost of the components and installation. But the newly introduced incentive program adopted by the California Energy Commission (CEC), which offered buy-down rebates for small wind systems, inspired him to take a second look.



He crunched the numbers and discovered that the state's rebate and the $2,000 federal tax credit would cover 50% of the system's cost. "We never thought we'd see the day when wind power was affordable," Tom says, "but we were thrilled when it was finally within our reach."

By 2003, Tom and Robbin had saved what they needed and were ready to commit. After visiting several homes with turbines and weighing all the options, they decided on a grid-tied system without battery backup. "We realized that a stand-alone wind system with batteries was going to require a lot of maintenance as well as have higher up-front costs, and while we could have dealt with that, we decided it was more important to give back to the community," Tom says. "It made more sense to feed our excess power back to the grid rather than charge batteries in a stand-alone system and waste any excess power generation."

An online advertisement led the couple to a small installation company in nearby Tehachapi, and after the initial consultation, they hired the crew to install a 10 kW Bergey Excel-S turbine on a 60-foot, guyed tilt-up tower. According to manufacturer estimations, this turbine, with their class 5 wind resource, could produce enough electricity (more than 1,400 kWh per month) to support their electricity needs.

The Houchens chose to site the tower approximately 90 feet east of the house—far enough to lower the tower as necessary but close enough to minimize voltage drop in the wire run to a well shed, which houses the Xantrex GridTek 10 inverter.

Tom tapped into his local resources and purchased a used tower for $1,200 from the Tehachapi Wind Farm. This tilt-up tower—which features a pulley system and a hinge at the base—was hauled to the site in two pieces. Though the tilt-up design required more area for the footprint of the guy wires, the promise of easier turbine maintenance justified the choice for Tom. "Being able to maintain the wind generator at ground level rather than having to climb the tower was important to us," he says.

To keep installation costs down, Tom and his brother used a trencher to dig the trenches themselves, which were needed to run the cable from the tower to the well house. They also

PV System Tech Specs

Overview

System type: Grid-direct solar-electric

Location: Rosamond, California

Solar resource: 6.6 average daily peak sun-hours

Average monthly production: 443 AC kWh

Photovoltaic System Components

Modules: 12 BP175B, 175 W DC STC, 35.8 Vmp

Array: Two six-module series strings, 2,100 W STC total, 214.8 Vmp

Array installation: Professional Solar Products GroundTrac ground mounts—south-facing at 19-degree tilt

Inverter: Xantrex GT3.0, 3 kW rated output, 600 VDC maximum input, 195–550 VDC MPPT operating range, 240 VAC output

System performance metering: Xantrex GT built-in meter

System Costs

Initial Cost: $16,209

Less Incentives, Rebates: California Solar Initiative $4,471; Federal Tax Credit $2,000.

Final installed cost: $9,738

Wind Tech Specs

Overview

System type: Grid-direct wind-electric

System location: Rosamond, California

Wind resource: Class 5 (14 mph average wind speed)

Production: 1,400 AC kWh per month

Wind Turbine & Tower

Turbine: Bergey Excel-S

Rotor diameter: 22 ft.

Rated energy output: 900 AC kWh/month at 12 mph

Rated peak power output: 10 kW at 31 mph

Tower: 60-ft. tilt-up tube tower, guyed

Balance of System

Wind turbine controller: Internal to inverter

Inverter: Xantrex GridTek 10, 240 VAC output

dug the holes for the tower's four anchors—which had to be 4 feet wide and 5 feet deep for adequate anchoring in the friable desert soil.

Mounting Frustrations

Working with the installer proved frustrating as time went on. "The crew had the technical know-how to do the actual installation, but it was a rather unorganized operation. We ended up having to fetch the parts from all over the valley and use our tractor trailer to haul some equipment to the site," Tom says. "It took about six months to get the turbine up and running versus the one month promised, and slowed the rebate process."

Adding to the aggravation, Tom and Robbin had to wade through miles of red tape with their local utility, Southern California Edison (SCE). "The state put all the laws and regulations for net metering and rebates in place, but it seems that they failed to arm some utility companies with systems and procedures to handle residential installations," Tom says. "[At that time] we, like many homeowners in the region, were [renewable energy] guinea pigs for Southern California Edison."

For months, Tom and Robbin took turns going back and forth with SCE to work out the kinks with the grid connection. But even after the system finally went online in October 2004, they were plagued by countless billing errors. "They didn't have a billing system for net metering, so they had to do it by hand," Robbin says. "For the first couple of years, we received handwritten bills and crude spreadsheets of our usage."

They learned to look for the fine print and keep tabs on their usage. After months of statements that showed zero balances, a bill for more than $1,100 arrived in the mail. "Apparently, if at any time you produce more than you use, you are defaulted to a yearly bill," Tom says. "It was really just the utility's way of making the net metering process easier on them. It took three months to sort out that mess and settle the bill."

Though their system initially produced more electricity than they used, the tide later turned. Adding two 2.5-ton air conditioners pushed their usage past their system's production. But since they had been unknowingly defaulted to a yearly billing cycle, they were completely blindsided by the final bill.

On the upside, Tom says they've only had minor repairs and maintenance to contend with. He replaced a coupler that the installer (who's no longer in business) jury-rigged after failing to order the manufacturer-recommended part. And, when the numbers on the LCD screen of the inverter became fractionalized and difficult to read, Tom contacted Xantrex and put the warranty to work. Xantrex supplied a new LCD screen, which Tom installed in about an hour. A few times per year, he lowers the tower, using his tractor to work the pulley system, and cleans the blades and turbine.

Solar Ready

Despite the rough start with the wind installation and

Left to right: The GridTek inverter for the wind system and the GT3.0 for the PV system.

net metering, Tom and Robbin were pleased with their investment and excited to do more with renewable energy. It took a few years to build up their savings, but by 2006, they were ready for the next step—a solar-electric system. With a daily average of 6.6 peak sun-hours, the valley is ripe for solar power—so much so that commercial solar farms have been popping up in the area.

This time, Tom and Robbin were extra cautious when choosing an installer. After thoroughly checking references and visiting several completed systems, they went with a solar program through their local Home Depot, which offers systems using BP modules. The store paired them up with Sharpe Solar Energy of Bakersfield, a solar integrator with more than 30 years' experience.

Since space was not a concern and climbing on the roof to rinse dust off the modules was less than ideal, Tom chose to ground-mount the modules about 75 feet south of the turbine and 85 feet from the well house. The 2.1 kW array consists of two six-module strings tilted at 19 degrees for optimal summer performance. This setup helps offset the Houchens' peak demand for air conditioning—plus California Solar Initiative (CSI) rebates are higher for arrays angled perpendicular to the summer sun.

The installation was fairly straightforward, taking only two weeks from start to finish. The biggest delay, says Tom, was getting a mixer to deliver the concrete needed to anchor the galvanized pipes for the array framework. Instead of waiting on the truck, the crew mixed and poured the concrete themselves. Assembling the framework and wiring the system took only a couple of days after that.

By this time, the state had turned the rebate fulfillment over to the utility companies. Still in its first year of handling the process, SCE was slow to inspect the system and, Tom says, disorganized with all the paperwork. "It was really confusing and frustrating at times, but thankfully, the installer went back and forth with them and took care of it."

Ultimately they were able to take advantage of the CSI rebate for PV systems—just over $2 per watt. That, coupled with the $2,000 federal tax credit, reduced the up-front cost of the system by about 25%.

Farming the Sun

It's been a decade-long journey, but Tom and Robbin couldn't be happier with their RE investments. As of July 2008, solar and wind power are producing more energy than their household—which now includes both Tom's and Robbin's mothers—consumes.

Though Tom and Robbin do not have wind performance data (due to a faulty production meter), the wind contributes significantly to the overall energy produced. Using Bergey's online Wincad Performance Model, it is estimated that this wind system provides about 1,400 kWh per month.

The solar resource at this site—a wide-open solar window from dusk to dawn—has proved to be very impressive. In its first seven months of operation, the 2.1 kW PV system has produced 3,100 kWh—about 34% more energy than estimated from the National Renewable Energy Laboratory's PVWatts program.

But the Houchens' story does not end there. In addition to plans to wean themselves from propane water heating to electric tankless water heaters, Tom and Robbin may join the area's rapidly growing community of solar farmers. A commercial solar company approached the couple about leasing the lower half of their property for a solar farm that would be home to megawatts of PV generating capacity. "It's nice to be able to generate our own electricity," Robbin says, "but it would be wonderful to make an even larger contribution."

Access

Home Power associate editor **Kelly Davidson** (kelly.davidson@homepower.com) recently moved to Takoma Park, Maryland—a nuclear-free community since 1983. She and her fiancé are still saving all their pennies to buy land and realize their green dream—a solar-powered, super-insulated, barn-style home made from reclaimed and recycled materials.

Tom & Robbin Houchen • houchetp@hughes.net

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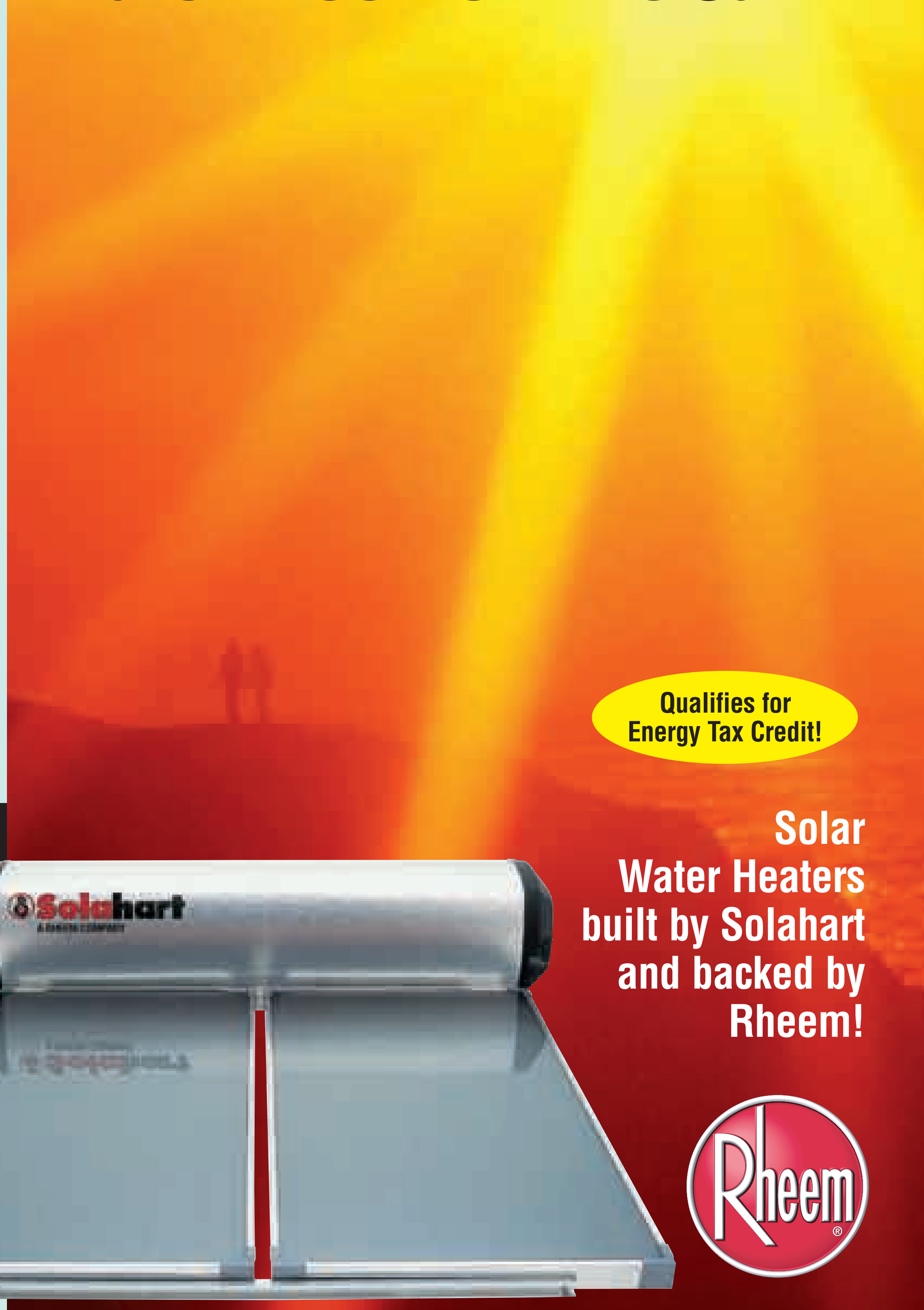

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OFF OR ON GRID?

GETTING REAL

by Ian Woofenden

Dreaming of cutting the cord and getting rid of the big bad utility? Perhaps you should think again. Renewable electricity has lots of benefits, but stand-alone (off-grid) systems are more expensive and complex, and require more maintenance than batteryless grid-tied systems. And there are other big advantages to installing renewable energy systems *on* the grid. Before you make your decision about whether to be off grid or not, let's take a closer look at the pros and cons.

System Types

Three basic categories of renewable electricity systems are available today (though the future may hold more!).

Stand-alone off-grid systems are completely independent of the utility grid. With the exception of direct-use systems like water pumping or PV-powered ventilation, stand-alone RE systems must have batteries to provide energy storage during times of low input or high usage.

Battery-based grid-tie systems are quite similar to stand-alone systems. They also use batteries, but they are connected to the utility grid, so they can send out to the grid any surplus electricity generated by the RE system, and use utility electricity when needed.

Batteryless grid-tie systems are the simplest of all systems, having only the energy generation technology (be it PV modules, or a wind or microhydro turbine) and an inverter connected to the utility grid. They do not have batteries, which points to their primary drawback—they have no backup capability. When the grid goes down, these systems also shut down.

Off-Grid Advantages

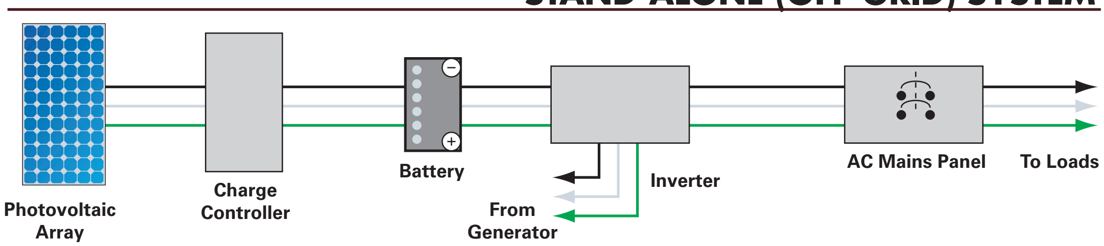
Independence is chief among the reasons for wanting an off-grid system where the grid is available. Off-grid systems are not subject to the terms or policies of the local utility, nor are system owners subjected to rate increases, blackouts, or brownouts.

If you're shopping for rural property, you'll probably find that off-grid parcels are less expensive. Most people aren't ready to take on being their own utility, and the land is priced according to this value system. Being off-grid can also be cheaper than getting a utility line extended to a property. But bear in mind that with off-grid renewable electricity systems, there are up-front *and* ongoing costs.

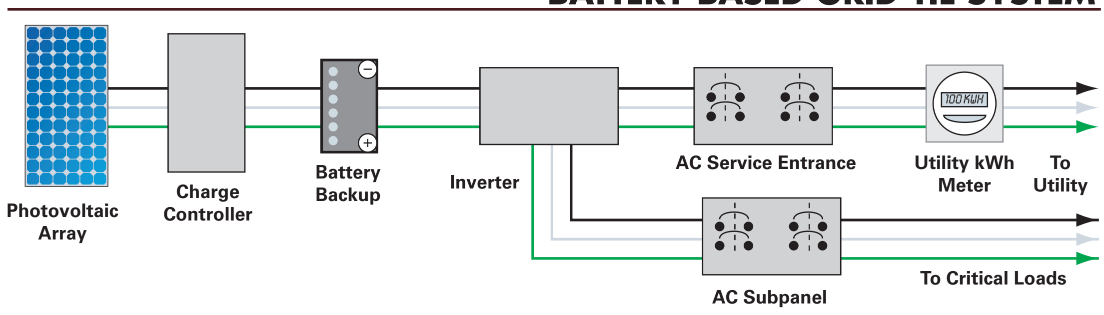
Off-grid systems may have a slight edge over grid-tied systems when it comes to expandability. While both are modular, it's often easier to grow an off-grid system as you can afford it. In fact, many off-gridders with limited incomes find this to be the norm—gradual weaning from fossil-fueled generators by adding more renewable capacity. With lower array voltages (12 to 72 VDC nominal), one to four modules can be added at a time. Batteryless grid-tie systems run in the 150 to 600 VDC range, and specific inverters have voltage windows and efficiency curves, so that adding to them requires more modules and, possibly, another inverter.

SYSTEM TYPES

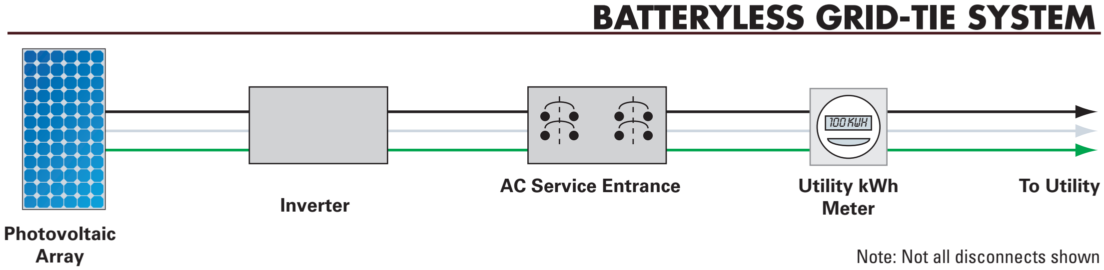
STAND-ALONE (OFF-GRID) SYSTEM



BATTERY-BASED GRID-TIE SYSTEM



BATTERYLESS GRID-TIE SYSTEM



Note: Not all disconnects shown

An off-grid system will require batteries and a charge controller, as well as an inverter and disconnects common to all system configurations.

Unless you can afford an oversized system, off-grid systems tend to force you to use electricity efficiently. This is a big advantage if you also hold environmental values. Some of the most energy-efficient homes in the country belong to off-grid folks. When you have to make all your energy with only the available resources at your site, you *think* about how to use that energy wisely.

There are many less tangible advantages of being off grid as well, including the satisfaction and peace of mind that goes with using electricity responsibly. And maybe your neighbors will begin to think you are way ahead of your time.

Off-Grid Disadvantages

When you make the decision to go off grid, you take on the duties of the cursed utility you were trying to avoid. My experience is that you tend to curse them less and appreciate them more as you tackle these responsibilities.

First and foremost, making all of your own electricity is costly. If you are already on the grid, it's unlikely that installing an off-grid RE system will provide you with cheaper electricity, unless your area has generous incentives, very high utility rates, or both. (Note that most financial incentive programs apply to on-grid systems and do not apply to batteries.) Of course, if you're a long-term thinker, this changes the picture. But most people conclude that "going off grid" to save money is not a winning concept. With existing off-grid property, you need to weigh the cost of line extension against installing an off-grid RE system. In some areas, utility line extension can exceed $20 per running foot.

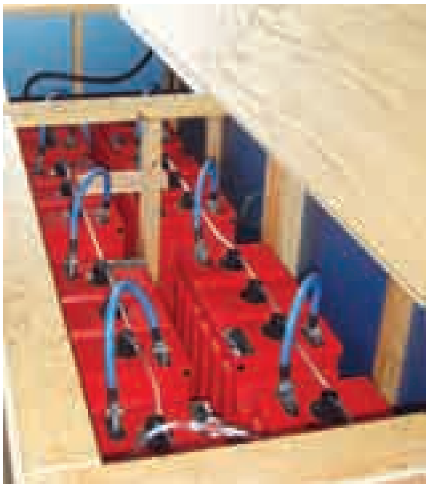
System maintenance and troubleshooting are serious, ongoing responsibilities with off-grid systems. When you pay your utility bill, you're paying for those hard workers in business suits and coveralls to take care of things. If *you* are the utility, you have to do the work all by yourself, *plus* buy the coveralls.

Off-grid systems use batteries to store electricity and provide it for your home, but batteries don't last forever. In fact, they will need replacement every five to fifteen years (typically less than ten, unless you have deep pockets for high-quality, industrial-type batteries). A minimal bank of batteries will cost at least $1,000, and long-lasting industrial batteries for the same application might cost three to four times that much. And it's not just the cost in dollars that's a disadvantage. There's maintenance and replacement time, aching backs from lifting that heavy metal, and perhaps labor cost—and then there's the environmental cost of making, moving, recycling, and replacing all that lead.

Batteries have another, less tangible cost, and that's energy waste. At their best, batteries are 90% efficient. That means if you put in 10 kilowatt-hours (kWh), you will get out less than 9 kWh. As they age, their efficiency drops further, and they are also affected by temperature. All this adds up to more energy waste the larger, older, hotter, or colder your battery bank is.

In comparison to grid-tied systems, stand-alone systems have another serious drawback—wasted surplus energy. When a grid-tied renewable electricity system makes more than the homeowners use, the surplus is fed to the utility,

Large battery bank and engine-generators are commonplace components in off-grid systems, and significantly increase the initial and long-term operating costs.



System Cost Comparisons*

Item	1 kW System: Batteryless: 2 kW Inverter	1 kW System: Stand-Alone**: 2.5 kW Inverter & 15 kWh Battery	3 kW System: Batteryless: 3 kW Inverter	3 kW System: Stand-Alone**: 4 kW Inverter & 15 kWh Battery	5 kW System: Batteryless: 5 kW Inverter	5 kW System: Stand-Alone**: 2, 2.5 kW Inverters & 40 kWh Battery
PV array & mount	$5,800	$5,800	$17,700	$17,700	$28,500	$28,500
Charge controller	—	700	—	700	—	1,400
Batteries	—	3,100	—	4,800	—	7,000
Inverter	1,900	2,300	2,600	3,200	4,050	4,650
Disconnects, wiring, etc.	750	1,700	1,800	3,200	2,600	3,500
Labor	1,200	2,100	3,600	5,900	5,600	8,900
Low End of Cost Range (-10%)	$8,685	$14,130	$23,130	$31,950	$36,675	$48,555
Total Cost	$9,650	$15,700	$25,700	$35,500	$40,750	$53,950
High End of Cost Range (+10%)	$10,615	$17,270	$28,270	$39,050	$44,825	$59,345

*Real-world figures will vary depending on homeowner and designer preferences.
**With engine-generator backup.

creating an energy credit and allowing the system to always run at full capacity. Nothing is wasted, and the grid is figuratively (not literally) 100% efficient—you get credited for all that you throw their way. When you're off grid, your surplus must be used or it will be wasted. With most off-grid PV systems, the array simply gets turned off by the controller when the batteries are full, so the energy is never generated. With most wind and hydro systems, the excess energy is shunted to a dump load, typically an air- or water-heating element. Savvy off-gridders are aware of their system operation, and change their energy-use habits when there's a surplus—like choosing to do laundry in the middle of the day. But it's not automatic, and it takes some social adjustments to switch from energy sipper to energy gorger depending on the weather.

Most off-grid systems need a backup engine-generator, and this is another big disadvantage of these systems. Generator electricity is expensive when you calculate the cost of purchasing, fueling, and maintaining these dirty, noisy machines. And if you buy a cheap model, you might end up with what veteran off-gridder and RE installer Roy Butler calls an "800-hour throwaway" and have to replace it sooner than you wished.

If living off grid sounds like a bit more trouble than you expected, good! I'd like you to be successful with your renewable energy plans, and being realistic is a good first step. My family moved off grid in 1981, and my wife and I have raised a raft of kids and run several businesses from home, so I know that it's not always a picnic. We've been through multiple generators, and have had hard times when we had to wait for the weather to change before doing the laundry. The social and familial implications of living with a variable energy source shouldn't be underestimated!

Living off-grid can be satisfying, but it's also a big responsibility. It's necessary to be willing to flex your electrical

Howard and Carol Pellett paid the extra cost of batteries to enjoy the security provided by their grid-tied battery backup system.

activities with the changes in the weather, or be willing to start up a fossil-fueled generator whenever nature is not cooperating with your energy plans. If you're a city dweller who gets impatient when the traffic light takes a while to change, imagine how you'll handle waiting for the sun to come out or for that mechanic to fix your generator.

On-Grid Advantages

Using renewable energy on the grid avoids most, if not all, of the disadvantages of being off grid. The utility is like a big, 100% efficient battery that can absorb all your surplus energy. In addition, you can lean on it as hard as you want to for as much additional electricity as you might need. If you can't afford a renewable-electric system large enough to supply all your needs, you can install whatever portion you can afford. If you're off grid, you have to make it all, one way or another, and if you're strapped for cash when you're putting in your system, you'll end up making a lot of it with fossil fuels. When the grid uses fossil fuels, at least it uses them more efficiently, and with less noise and pollution than a home generator.

With grid-tied renewable energy systems, there is no absolute need to conserve electricity or change your lifestyle. You can choose to live the same way you lived before you installed an RE system. Your system will offset some or all of your usage, and your daily life can continue unchanged.

If you decide on a grid-tied system with battery backup, you can have the best (and some of the worst) of both worlds: You can have the independence and backup of a stand-alone system, still be able to use at least some energy during utility outages, and have the ability to sell your excess energy to the grid.

The simplicity of batteryless grid-tied balance-of-system equipment is hard to beat.

Grid-tied systems with battery backup allow you to sell surplus renewable electricity to the grid and provide electricity for critical loads during utility outages.

For all these system types, investing in a PV system also means locking in the long-term pricing of your electricity. With a photovoltaic system, you are buying 40 to 50 years of electricity at a fixed price, while maintaining the benefits of being on grid.

On-Grid Disadvantages

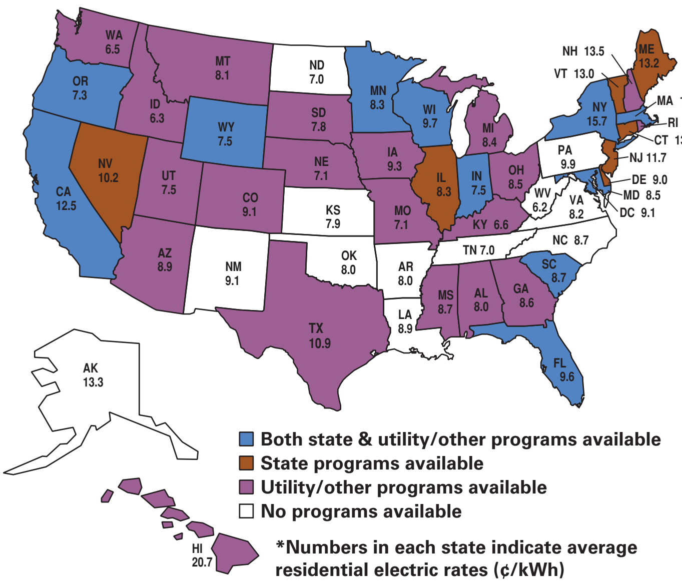
One major disadvantage of having a grid-tied system is that you have less incentive to conserve. That inviting wall receptacle will take whatever you plug into it, and no "depleted battery" warning will sound when you use a lot of electricity. If you can manage to bring an off-grid mindset to your on-grid home, you'll make the most of your RE investment.

With batteryless systems, you'll have no backup. In most cases, this is not a very serious drawback. The utility grid is quite reliable in most urban places in the United States, with outages occurring only a few times a year for a few minutes to a few hours. But if you have frequent or long outages or critical loads, a batteryless system will frustrate you and maybe even cost you an occasional freezer full of food.

However, battery-based grid-tie systems typically only provide modest backup. To power *all* of your loads during an extended outage when there's no sun would require a very large battery bank, which would be expensive and make for a less efficient renewable energy system.

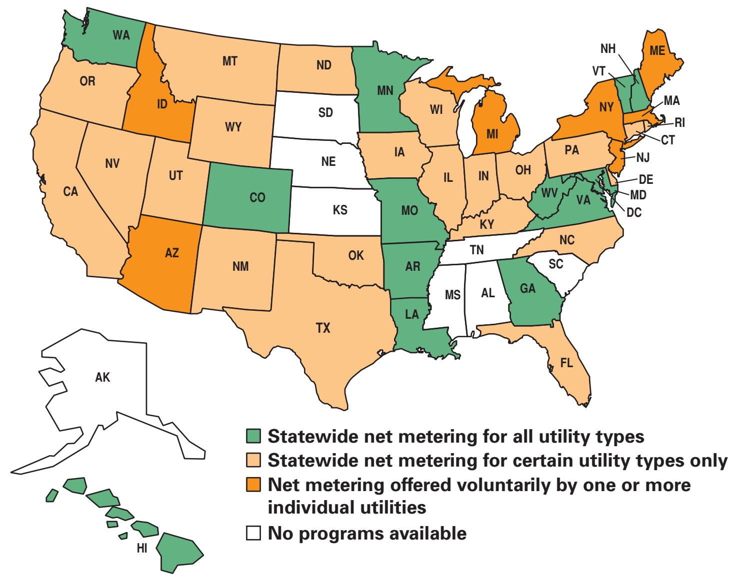
For all grid-tied systems, you also have interconnection red tape. This can range from simple to onerous, depending on the authorities and utility you have to deal with. In places

RE Incentive Programs



Source: Energy Information Administration, 2005. Year-to-Date Average Residential Retail Price of Electricity, revised June 2007

Net Metering Status



Source: DSIRE USA, July 2008

where RE systems are becoming common, there may be a greased path through your inspection agencies and utility, once you know the right people to deal with and the right forms and procedures. If you're pioneering a new path, you might run into a lot of roadblocks, such as public servants or utility personnel who are ignorant of these systems, or burdensome gear or paperwork requirements.

Weighing the Costs

So how do you make the choice between being on grid and off grid? This is a personal decision, based on finances and personal values. First, weigh the costs. A battery-based system generally costs about 30% to 40% more than a batteryless grid-tie system, and maybe as much as 50% more, depending on the battery bank size and other components. The other major consideration is the cost of utility-line extension. This can range from zero for properties close to existing utility lines to hundreds of thousands of dollars for properties that sit a long way from the line. Get quotes from solar contractors and from your utility, and then crunch the numbers.

Values are a bit harder to evaluate objectively. I know people who were faced with $25,000 line extension costs to get utility electricity to their property. They opted to stay off grid and, in the end, invested more than $75,000 in their wind- and solar-electric systems. For this, they get satisfaction, independence, and no utility bills. Obviously, the up-front cost was not their highest consideration—they have other values. But they invested a lot of money and time initially, and will have the continued investments in time and money to keep their systems running. Others may decide to spend anywhere from a few thousand to tens of thousands of dollars for the reliability, efficiency, and convenience of having the grid, even if they invest in an RE system that will offset all of their usage and bills.

From the perspective of more than 25 years of off-grid living, my advice is not to unplug from the grid if it's there. Of course, there are exceptions to every bit of advice, and if you live where net metering (selling back to the grid for credit) is not available or monthly base charges are high, you have a different situation. But in general, "greening up" the grid with your renewable electricity will benefit you, the environment, and your community better than cutting the cord.

The author and his family have lived off grid—courtesy of solar-electric, wind-electric, and solar thermal systems, plus a well-developed energy conscience—for more than two decades.

Access

Ian Woofenden (ian.woofenden@homepower.com) has lived off grid with his family in Washington's San Juan Islands for more than 25 years.

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THE UNIMAGINABLE FUTURE OF RENEWABLE ENERGY

Off-grid vs. grid-tie? Both? Neither!

by Christopher Freitas

What will be the most common type of renewable energy system of the future—off-grid or grid-tie? My usual answer is, "Both," meaning that there will just be more of each type, depending on the circumstances. But lately I have realized the most common renewable energy (RE) system of the future might actually be neither of these.

Take computers as a parallel example. Back in the early 1980s, the big question among computer geeks was whether computers of the future would be personal or mainframes—both were available and being used in ever-growing numbers. The interesting part is that neither solution ended up dominating. Something else did—the Internet, an amalgam of both personal and mainframe computers, as well as many things we never imagined. And when you're viewing a Web site through a wireless Internet connection, for instance, it doesn't matter what kind of computer you're using.

Renewable energy systems are similar—we really can't imagine what the future will look like. The eventual widespread system will probably end up as a mixture of both off-grid and grid-tie technologies coupled with some new ideas few have imagined yet. In the future, the terms "off grid" and "grid tie" may just be relics, just as "personal" and "mainframe" are to surfing the Web.

Blast to the Past

Most new technologies first become popular with extreme or fringe applications. With RE, it was independent-minded back-to-the-landers who wanted off-grid systems in remote areas and dedicated environmentalists who wanted to reduce their environmental footprint with batteryless grid-tie systems. But these two markets are very limited in size. The majority of people are "in the middle" and will require more benefits and features to get motivated to spend the money and time to incorporate renewable energy into their daily lives. The solution they choose might be very different than what is currently available, possible, or even legal.

We don't always notice the scale of the changes that occur around us during our lives. As a young child, I remember turning over the telephone to find a sticker on the bottom that said, "Property of Pacific Telephone." When I asked my father about it, he informed me that everyone leased their telephones from the phone company and paid a monthly fee for each phone used. He emphasized that you could not just take any old phone you found and plug it into the phone lines—it might damage the phone network. I also remember that when the first fax machines and personal computers were being used, the phone company required you to have special "data" phone lines installed with extra fees attached. Consumers had no choice in who provided their phone service—there was no competition.

Today, Pacific Telephone doesn't even exist and consumers now have a choice of phone service providers. Nobody leases their telephones from their service providers anymore. You can plug a fax or computer into a wall jack without causing the phone system to crash. And your "local" service provider might be located in an entirely different part of the country. Yet it all still seems to work fine and, thanks to competition, prices have dropped. The latest trend is to forego traditional hard-wire phones at home. Instead, many people use cell phones or Internet-based phone services. Both wireless and networked solutions coexist side-by-side and also work together.

Fast Forward to the Future

Today's utility companies remind me a lot of the old phone companies. They have many people convinced that permission is needed to connect renewable energy sources to "their" grid, which was actually paid for by the consumers under the utilities' monopoly status. The utilities view renewable energy as a competitor—something they need to control if they have to allow it. And, just like the telephone companies used to do, they want to require special rules and additional fees for using RE. At some point, utilities will realize that they should not only allow the widespread use of renewable energy, but that their very existence requires that they embrace it or face extinction, just like many of the old telephone companies that were slow to change.

The most common RE system 20 years from now might be something that is just as unimaginable as today's Internet was three decades ago. Future-flexible RE systems might connect to a utility network when it makes sense to but also be able to work independently. There might even be independent "open" power networks similar to today's wireless networks, where people can distribute the energy produced by their RE systems to their neighbors or provide RE access to those less economically able to afford it. And the role of the utility in the future might be very different than it is now—if they still exist at all.

"At some point, utilities will realize that they should not only allow the widespread use of renewable energy, but that they must embrace it or face extinction."

Beyond utilities, getting people to embrace and utilize renewable energy will require a completely different relationship with electricity—how it's consumed and what its role is. This might sound like a quantum leap, but changes happen all the time—in fact, they are inevitable. The renewable energy industry needs to seek out, invent, and take advantage of all new opportunities to reach more people and make RE a part of everyone's daily lives.

Access

Christopher Freitas (cfreitas@outbackpower.com) is a cofounder of OutBack Power Systems, a U.S.-based manufacturer of power electronics for RE applications. Freitas has worked in the RE industry since 1985.

Financing the Solar Dream

Leases & Power Purchase Agreements

by Charles W. Thurston

New financing options—power purchase agreements and leases—are helping homeowners take part in the solar future.

Leased systems are becoming a popular option for consumers who want to minimize their up-front costs. Retired university professor Paul Bartlett is pictured with the SunRun-owned array on his roof.

Courtesy www.sunrunhome.com

Some homeowners have liquid investments or savings to purchase a solar-electric system outright, spending $12,000 to $60,000-plus. Others borrow what they need through a home-equity or personal loan. But many homeowners without access to cash or credit on that scale must be able to minimize up-front costs to take advantage of the technology. This has prompted installers to bring new payment offerings to the residential market. With moving targets for federal and state incentives, two options—power purchase agreements and leases—could be key to spurring residential solar adoption.

Courtesy www.solarcity.com

SolarCity's online calculator can quickly estimate PV system performance and savings.

Buying into Production

Power purchase agreements (PPAs) have been a financing tool used for large commercial power projects for decades, enabling developers to secure investor funding based on the end users'—in this case, utilities'—contractual payments for power. SunRun Generation LLC—a San Francisco-based solar energy company—was among the first to adapt this tool for the residential PV market.

Here's how their PPA works: For a fraction of the usual up-front cost, a homeowner can have a solar-electric system installed on their home by one of SunRun's participating installers. SunRun then owns and operates the system, and sells the generated electricity back to the homeowner at a low rate—usually a rate that increases much more slowly than utility rates—for the duration of the lease. Most customers still get two bills—one from the utility and one from the solar company—but, if the system was sized to provide 100% of their energy needs, the utility bill can be essentially eliminated.

SunRun's typical PPA is an 18-year agreement for the customer to purchase all the power produced by the system from the company. The monthly amount can vary seasonally but is generally predictable. Rates for SunRun agreements are typically 13.5 cents per kWh if about one-third of the installed cost is paid as an up-front fee. If a lower up-front payment is negotiated, the per-kWh rate the customer pays is greater. Based on an average utility bill of $100 and an installed system cost of $12,800, a consumer could expect to pay $4,267 up front for a system designed to meet all their energy needs. After the initial payment, the per-kWh cost is guaranteed by SunRun.

SunRun has more than 100 PPAs in California, and is considering expanding its service area within California and into other states. So far, SunRun has few competitors in the residential PPA market, but the competition is increasing rapidly—especially in California, where a law, signed by Governor Arnold Schwarzenegger in September 2008, streamlines the regulatory process for solar companies and developers.

Previously, solar companies had to go through the cumbersome process of registering as a utility with the state of California to use a PPA model. The new legislation (Assembly Bill 2863) removes several hurdles, clearing the way for PPA developments to become more easily installed in the state.

Open Energy Corp., of Solana Beach, is one of the companies that pushed for the new law. The residential solar-power company is helping lead the PPA revolution in California with its "Solar Community" model that uses PPAs to provide rooftop PV systems for real estate developments at no up-front cost to the homeowners or developers.

Last spring, the company broke ground on its first-ever PPA-based solar community at Pacific Station in Encinitas. Through a development agreement with San Diego-based John DeWald & Associates, Open Energy Corp. is financing $480,000 for the installation of 1.2 kW rooftop systems on each of the 47 condominium/townhomes at the mixed-use complex. In exchange, homeowners agree to buy back the solar electricity produced by the system from Open Energy Corp., at a rate lower than the rates of regular utilities. The project is scheduled for completion in 2009.

It's a win-win for all parties, says John McCusker, a representative for Open Energy Corp. The builder receives the tax breaks associated with using renewable energy, along with a faster rate of sale. Solar-equipped homes are selling four times faster in California than regular homes, he says. The solar-electric systems also allow the builder

A SolarCity-leased PV system on a Phoenix, Arizona, home.

What-if Scenarios

What if the lease or PPA provider goes bankrupt?
The PV system cannot be repossessed, and the homeowner cannot be held liable for the company's debt. Both SolarCity's and SunRun's financial partners would step in to make sure the systems continue to operate and generate both electricity and investment returns.

What if I want to move?
Both plans allow a new owner to assume the contract and also permit a buyout when a home is sold. (The value-added benefit of having an installed system can come into play here, since that typically translates into higher property value and a higher selling price.) Or the moving homeowner can pay to transfer the system to the new address, assuming it is within the company's service area.

What if my system doesn't produce what it is supposed to?
The lease method provides for a year-end credit if the system underperforms; with the PPA, you only pay for what you generate.

What if I want to upgrade my system?
The contracts only cover current technology. But both companies say that they will work with customers to minimize the costs of any desired upgrades. Neither plan provides for automatic upgrading of systems, even though the performance of newer systems will likely improve as the industry matures.

What if I want to increase the size of my system?
Neither program is designed to accommodate system expansion once the basic inverter infrastructure is installed, and the inverter's rating will limit how many modules can be added to a system. New mini-inverters intended to be integrated with each module could make subsequent expansion easier in the future.

to meet Leadership in Energy and Environmental Design-certification requirements.

But the benefits for the homeowner go beyond no up-front costs. Other pluses include the added resale value for the home, the possibility of selling the house faster, a lower electric bill each month, and the satisfaction of using eco-friendly renewable energy.

Other companies are developing PPA programs as well. Berkeley's Helio Micro Utility entered the residential solar PPA market last summer, and Tioga Energy of San Mateo also launched a PPA finance program. As more institutional investors back solar integrators, PPAs are expected to flourish in the residential market.

"What we're starting to see is that innovative financial solutions from companies like ours will offer grid parity—the point at which electricity produced by PV is equal to or cheaper than grid energy—with some additional cost-savings benefit," says Nat Kreamer, president of SunRun. The company recently received $12 million in venture capital to help expand and fund its residential PPA program.

Leasing the Sun

After a market survey, SolarCity of Foster City, California, verified what most industry professionals already knew: The up-front payment is the largest deterrent to residential solar adoption. In response, the company teamed up with investment bank Morgan Stanley to pioneer a leasing program that makes solar electricity more affordable and accessible for homeowners.

"Our goal was to design a program that made it possible for families to pay less for clean power than dirty power, so they don't have to choose between helping the environment and saving money," says SolarCity CEO Lyndon Rive.

Their solar lease is typically structured as a 15-year agreement with a fixed monthly lease payment for the life of the contract and a guarantee of system production.

Comparison of Leasing & PPA Programs

	SolarCity's Lease	SunRun's PPA
Areas of operation	Arizona, California & Oregon	California
Contract length	15 yrs.	18 yrs.
Up-front cost	$0–$1,000 (0–2% of installed system cost).	Averages about 33% of installed system cost.
Monthly fee	Rate rises 3.5% annually. Utility electric bill savings greater than lease payments. Averages 11.2 cents per kWh over life of system.	Fixed price per kWh generated (13.5–15.0 cents).
Insurance	Homeowner chooses insurance provider.	SunRun insures the system.
Sales & installation process	SolarCity handles system design, financing, installation, maintenance, customer care, billing, and monitoring.	Homeowner chooses among area installers, SunRun partners provide third-party oversight. SunRun handles billing, maintenance, monitoring, and insurance.
System maintenance & component replacement	Free, all-inclusive, and guaranteed. Lessor guarantees kWh production, which motivates appropriate maintenance. Remote monitoring efficiently identifies problems. Provides for inverter or other component change-out when needed.	Free, all-inclusive, and guaranteed. Regular cleaning and maintenance included. PPA obligates kWh production levels, which motivates appropriate maintenance. Remote monitoring efficiently identifies problems. Provides for inverter or other component change-out when needed.
System monitoring	"Smart" metering tracks and micromanages system optimization. Customer can view output and performance status via Web.	"Smart" metering tracks and micromanages system optimization. Free revenue-grade cellular monitoring system tracks system output and ensures optimal performance.
Performance guarantee	Energy output guaranteed over life of system. Allowances for PV module and other system degradation are covered under the contract. Refunds for shortfalls from guaranteed production issued to customer.	Customer receives rebates if system underperforms. Allowances for PV module and other system degradation are covered under the contract. Refunds for shortfalls from guaranteed production issued to customer.
Excess production rights	Homeowner gets 100% of excess production.	Homeowner pays SunRun for each kWh produced.
Options if homeowner sells home	New owner can assume agreement, or homeowner can buy system or pay to relocate the system to the new home—if home is within the company's service area.	New owner can assume agreement, or homeowner can buy system or pay to relocate the system to the new home—if home is within the company's service area.
Contract buyout options	Prorated buyout option at five-year intervals.	Prorated buyout option available after the first year.
Options at contract end	Renew the agreement, purchase system, or upgrade the system under new lease—though costs are not necessarily guaranteed.	Renew the agreement, purchase system, have system removed at no cost, or upgrade the system—though costs are not necessarily guaranteed.
Buyout cost at contract end	Fair market value, typically 20–30% of installed system cost.	10% of system cost.

The lease payment and guaranteed production are largely based on the individual system's size, but other siting factors—including tilt, orientation, and shading—are taken into account. The more optimal the conditions, the higher the guaranteed power production, and the lower the lease payment.

Any production above the guarantee is applied against usage and may earn utility credits. However, such credits are rare, since SolarCity slightly undersizes most systems and primarily targets the most expensive peak utility rates. This keeps the lease payment down and maximizes the savings for the customer. Homeowners can opt to lease a larger system to offset up to 100% of their electricity usage.

SolarCity's lease was just what John and Margaret Stubblebine needed. For years, the couple had been thinking about adding a solar-electric system to their home in Cupertino, California, but the cost kept them from following through with the idea. Then, they heard about the leasing program and figured it couldn't hurt to get an evaluation.

"The assessment showed that we would be spending less for electricity after the solar installation than we would have without it," John says. "With energy prices rising so quickly, the solar lease fixes our costs into the future. So, if—or more like *when*—electric rates rise steeply, our rate will be stable, and we will save much more money."

Given the Stubblebines' $158 electricity bill, SolarCity recommended a 30-module, 6 kW system that would offset up to 1,100 kWh per month and reduce their utility bill by about $116 per month. After factoring the reduced utility bill and a monthly lease payment of $107, the system delivers a net savings of $9 per month.

Other companies are following SolarCity's lead. BEohana Solar Corp. and Power Solutions of San Jose are also offering solar leases at the urging of the city mayor.

Since the start of its solar lease program in February 2008, SolarCity has tripled its business in the first few months, largely due to an introductory (now expired) no-money-down lease in Arizona, California, and Oregon. Though preliminary numbers look good for leasing programs, not everyone can jump on this bandwagon. As with low-interest financing options for any consumer product, most solar leasing programs require good credit to qualify (typically a credit score of 720 or higher).

Beyond the West, the state of Connecticut rolled out a $39 million solar lease program funded by U.S. Bancorp. Through the Connecticut Clean Energy Fund, a combination of rebates and tax credits will lower the cost of residential solar leasing. This is the first time a ratepayer-funded program has partnered with private financial institutions to leverage federal tax credits, with the goal of making residential solar energy more affordable. The program's aim is to install 1,000 systems for low- and medium-income households in the state.

Weighing the Options

Similarities between solar PPAs and leases are greater than the differences (see "Comparison" table). The key distinction is the cost over the system's lifetime. If cash flow is an issue, the lease is the best way to go, since there can be no down payment. If you can afford to invest up front in part of the system cost, you'll pay less as time goes on, and your savings can be greater at the end of the contract. In that case, a PPA may be more beneficial. However, representatives from both lease and PPA companies insist that the outcomes are not that different at the end of the contract.

"There's no one way that is really cheaper than another," says Mike Hall, president of Borrego Solar Systems, which offers PPAs through SunRun and commercial leases financed by Bank of America. "In the end, there's a certain amount of money that the bank needs to make, and the consumer is going to pay that money. It's just a matter of whether they'll pay it at the beginning, middle, or end, so be aware of the fine print and promises."

To simplify the overall process, California State Representative Mark Leno, of San Francisco, has introduced legislation that would require plain-language disclosures for lease, loan, or PPA offers. Under the proposed law, a state-required disclosure form—like those required for home or vehicle purchases—would take some of the work out of comparing the options. Until then, clear off a large swath of counter space for the paperwork.

One beauty of lease or PPA financing is that it protects you from increases in utility rates for the energy you generate and use. If you return power to the grid, you may even receive increased payments over time as rates rise.

While leases and PPAs are certainly viable options, Hall still encourages homeowners to buy if they can. "Don't underestimate the value of buying a system outright," he says. "The system can appreciate in value and is a good economic investment—but only the owner of the system will have the right to those benefits. With a lease or PPA, you are only entitled to what the contract provides."

Seizing the Solar Moment

A key consideration in choosing to adopt solar technology, be it through direct purchase, a lease, or a PPA, is when, if, and how rebates and tax credits will be continued or reinstated. Even though Congress extended the federal tax credits for eight years, state rebates and tax credits may likely diminish next year.

While a rebate may amount to several thousand dollars for a homeowner who purchases a solar system, the tax credits are mostly of interest to individuals and larger companies with sizable tax liabilities. Not surprisingly, solar companies have aligned themselves with well-funded Silicon Valley and Wall Street firms that seem to have an unlimited appetite for tax credits, which they can repackage in a variety of ways to their customers/investors. That's good news for homeowners who will need the financing assistance that a lease or a PPA provides.

The bottom line is that a solar lease or PPA makes it possible for *any* homeowner to stop talking about tomorrow and act now. Ask installers in your area about new financing programs, and remember—no matter your financial means, you can seize the solar moment.

Access

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Solar Lease & PPA Programs:

BEohana Solar • www.beohanasolar.com

Connecticut Solar Lease Program • www.ctsolarlease.com

Helio Micro Utility • www.heliomu.com

Power Solutions • www.solutionsforpower.com

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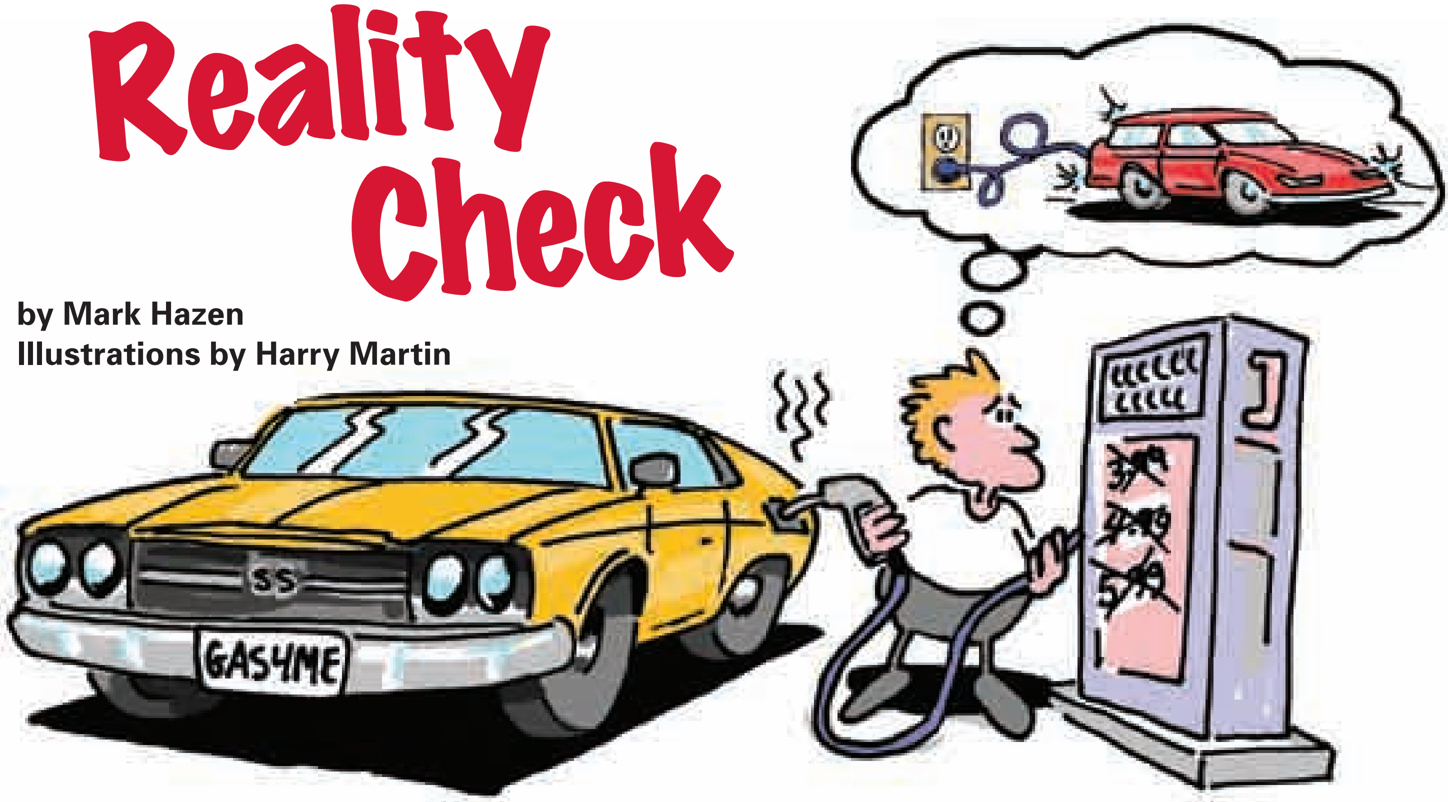
EV CONVERSION Reality Check

by Mark Hazen
Illustrations by Harry Martin



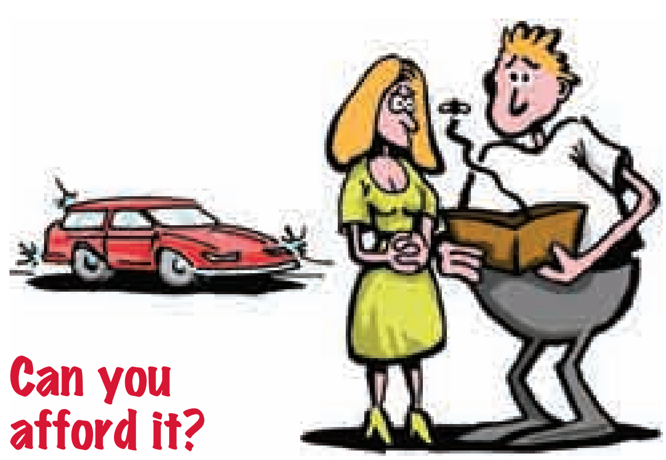
With every trip to the pump, converting your gas-guzzling car into an electric vehicle (EV) may sound better and better. The benefits seem obvious—freedom from rising fuel prices, the satisfaction of a do-it-yourself project, and best of all, a clean, quiet ride. But before you get totally swept away by the idea, there are some realities that you should consider—this kind of project is not for everyone.

Desire

The first reality is desire. Do you really want to take such a large step? While converting a car to run on electricity is satisfying, there is also a great deal of sweat that goes into it. To succeed, your motives must be strong and genuine. Wanting to be "green" is a good start, but there is more to it—you need the kind of passion that will sustain you through the ups and downs of a process that can be fraught with glitches. Put your desire to the test.

Budget

Depending on the "donor" vehicle, your EV conversion could cost between $8,000 and $12,000. Examine all costs before you begin and make sure the expense fits within your budget. Determine the online prices of components and, as with anything else, shop around. Keep in mind that buying products from a reputable dealer will often get you some phone help if needed. Don't forget that you can sell the discarded parts from your donor vehicle to offset the overall project cost. If you need to buy tools or rent a work space, then you'll need to factor in those expenses as well.



Can you afford it?

Ability

You will need basic mechanical and electrical skills to piece all the components together. Metal fabrication skills are important if you want to save money by making your own motor mount and battery rack(s), and these skills are needed for the installation of other components as well. You can purchase a prefabricated motor mount and battery racks—or hire someone to do the custom metal work for you. Welding skills may be worth learning—the more work you can take care of yourself, the lower the conversion cost will be.

As with many do-it-yourself projects, a knack for troubleshooting is critical. But if you do come up short on skills and abilities, don't throw in the towel. Pool your resources. An EV conversion can be a great group project. Compensate for your weaknesses by teaming up with friends, family, and even folks from a local EV group.

Means

Make sure you have basic mechanic's tools: socket, open-end, and box-end wrenches, along with a selection of screwdrivers and common power tools. Thread taps and dies may come in handy. You will also need an engine hoist to remove the old engine and put the electric motor in its place. If you want to make your own motor mount and battery rack(s), you will need a metal saw and/or a gas cutting torch. Last but not least, you will need a work area that is secure and available for the duration of the project.

EVs & the Environment

It is widely accepted that an EV (a.k.a. zero-emission vehicle) is cleaner than a gasoline-powered vehicle. But how much cleaner? Countless Web sites, blogs, and news agencies report an array of contradictory facts and figures. In most cases, it's a matter of conjecture.

Charging

Most experts agree the environmental impact of an EV largely depends on its charging source. The "cleanest" EV is one charged from renewable energy generated by the sun, wind, or water. The "dirtiest" EV is one charged from coal-fired electricity. (Note that coal-fired plants make up about 50% of all electricity-generating plants in the United States.) Many researchers conclude that EVs recharging from coal facilities still produce less carbon dioxide than gasoline-powered vehicles. According to World Resources Institute, CO_2 emissions in the United States would drop by about 20% if an EV recharging from coal-fired plants replaced every gasoline-powered vehicle on the road. Other sources predict more or less, depending on their prejudices.

Batteries

Another part of an EV's environmental equation is the production and disposal of lead-acid batteries—the chemistry most commonly used in EV conversions. Critics charge that the growing EV industry would significantly increase lead emissions into the environment through reckless lead smelting and recycling operations. Scientists and environmentalists have repeatedly poked holes in this claim. Modern lead smelting and recycling processes in the United States use effective pollution-control systems to minimize emissions. Some facilities, usually in countries with lax regulations, have been known to be careless, but battery manufacturers and the lead industry have mostly acted responsibly, having taken strong measures to improve battery recycling plants and furnace designs. In the United States, lead smelters are held to strict, ever-tightening standards by the Environmental Protection Agency.

According to Battery Council International (a trade organization for the lead-acid battery industry), more than 98% of all battery lead and plastic is recycled—possibly the most successful consumer recycling program in existence. Core deposits are required for lead-acid batteries at their time of purchase to ensure their return.

The Take-Away Point

If your mission is to truly go "green" by driving an EV, your best bet is to charge your vehicle with RE sources and be diligent about recycling your batteries.

EV Conversion Tasks

Task	Description	Time (Hrs.)	Difficulty
Planning	Educate yourself about step-by-step conversions: Tap into the Web or books on the subject. Talk to others who have done EV conversions—contact your local chapter of the Electric Auto Association (see Access). Assess the cost and your capabilities. Map out a plan, set your budget, and decide whether you want to use a kit or piecemeal approach.	20–50	Challenging
Vehicle selection	Find a donor vehicle to suit your needs and that will work well as a conversion. Take your time and choose wisely. Steer clear of wrecks and rusted bodies.	10	Easy to challenging
Component ordering	Shop multiple Web sites for your components: Compare prices, warranties, and shipping costs before ordering.	5	Easy
Work area and tool preparation	Clear your work area for your vehicle, parts, and tools. Make sure you have the tools you need, including an engine hoist.	10	Easy
Vehicle preparation	Move the vehicle into the work area and remove the engine, radiator, fuel tank, fuel lines, exhaust system, and emissions system. The transmission, clutch, and flywheel may also need to be removed but reused.	20–50	Challenging
Component manufacturing	Make your own motor mount and battery racking, if possible.	20–30	Challenging
Order batteries	Order batteries once you are ready for final assembly.	3	Easy
Conversion assembly	Install the motor, potbox, converter, contactor, AC/DC converter, driver's display, controls, gauges, safety mechanisms, etc. Wire the propulsion system, 12 V system, charging system, and the driver's displays and controls. Keep safety in mind, and follow manufacturers' instructions.	40–70	Challenging
Testing	Triple-check the wiring before charging your batteries and applying power. Then have someone else review your work. Before driving, inspect the battery charger, 12 V system, propulsion wiring, fuses, and battery terminal connections. Once on the road, start out slow. Test the brakes, accelerator, and the driver's display and controls. Make adjustments and repairs as necessary.	6	Challenging

Labor

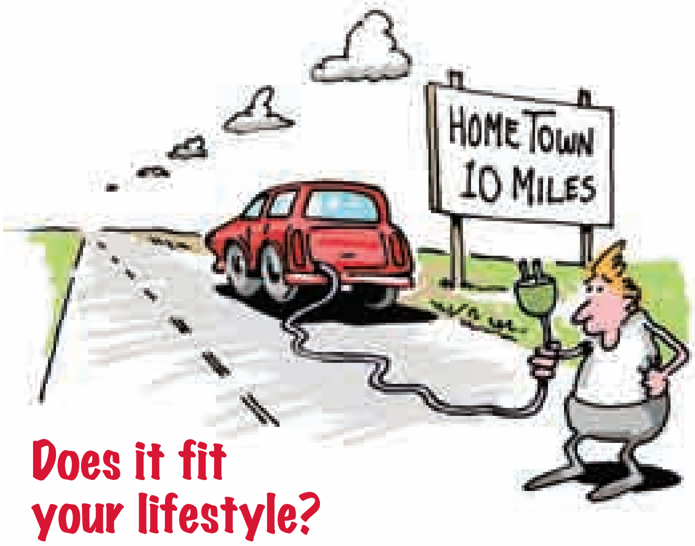
An EV conversion requires a significant time commitment. Plan on several months of weekends and evenings to complete your conversion. The table above shows an abbreviated list of what needs to happen and how long you can expect each step to take.

Do you have the time?

Finally On the Road

Turn the key, and all you'll hear is silence. Get up to speed, and you'll be amazed by the quiet ride. The only sound you'll hear is the tires on the road, and a subtle whine from the running gear. Driving an EV is great fun, but it's not without differences—slower acceleration, lower top speeds, and shorter range. Other quirks will arise, but they tend to be trivial—for example, electrical currents in an EV can interfere with AM radio reception.

Acceleration from a stop will be perky, but short-lived, in first gear. Most EV drivers start out in second gear and accelerate past 30 mph before shifting into third, then fourth gear. From there, you will gently reach top speed, which may range from 60 mph to 86 mph, depending on the number of batteries on board. Long, steep hills may be a challenge. If your top speed is too low, you may need to steer clear of high-speed roadways. Your battery pack's capacity will limit the range that the vehicle can travel. The ideal daily range is 20 to 30 miles to avoid overdischarging the batteries, which shortens their life.



Does it fit your lifestyle?

Maintenance

One beauty of EVs is that they require little maintenance—no more oil changes and no more trips to the shop for timing belts, water pumps, etc. The only significant maintenance requirement is the battery pack, which will require your attention on a monthly basis to keep the electrolyte level up and the terminals and battery surfaces clean. You will need to take voltage readings with a digital voltmeter regularly and, based on those readings, equalize the pack as necessary. Depending on vehicle use and battery type and care, you will also need to replace your battery pack every three to four years.

Will you do the chores?

If You Can't DIY, Just Buy

If you don't feel up to a do-it-yourself conversion project but you still like the idea of driving an electric vehicle, consider buying a new or used factory-made EV instead. Here are a few worthy of a test drive.

Buying New

EXV2 & ECV4. Minnesota-based E-ride Industries offers the EXV2 (a utility EV akin to a small pickup) and the ECV4 (a neighborhood electric vehicle, NEV, that resembles a mini-Hummer). A 72-volt lead-acid battery bank delivers a maximum range of 55 miles and a top speed of 35 mph. www.e-ride.com

GEMs. Global Electric Motorcars is well known for its curvy and futuristic fiberglass bodies. GEM vehicles have a range of about 30 miles and a top speed of 25 mph. Prices for GEMs range from $7,000 to $20,000, depending on passenger seating and options. www.gemcar.com

Tesla Roadster. The 2008 Tesla Roadster is newly in production—a great relief to those on the waiting list. The lithium-ion battery pack gives this all-electric sports car a purported 220-mile range on a single charge, with a top speed of 125 mph—but the $100,000 price tag is not for everyone. www.teslamotors.com

Buying Used

Factory-built rides. Chevy S10s, Ford Rangers, Toyota RAV4s, and Th!nk Citys are reliable and well-made vehicles that were manufactured during the mid-1990s through 2003. Vehicles in good working order can command prices between $30,000 and $40,000—or more.

Small-company production cars. EVs converted by small companies—including the Lectric Leopard and the Solectria Force (formerly the Renault LeCar and the Geo Metro, respectively) and Ford Escorts and Couriers converted by Jet Industries—have some operational quirks but make decent vehicles with some upgrades and reconfigurations.

Kit-built conversion cars. Vehicles converted by individuals with universal kits or custom kits—such as converted Chevy S10 trucks, Geo Metros, Dodge Neons, Volkswagen Rabbits, and Porsche 914s—range in price from a few hundred dollars to $10,000, depending on condition.

Custom-built EVs. A mishmash of old and new components come together in owner-built EV conversions that range in size, quality, and reliability. These can make great fixer-uppers, but it's typically easier to do a conversion from scratch than to upgrade one of these cars.

Where To Shop

Craigslist • www.craigslist.org
eBay • www.motors.ebay.com
Electric Auto Association • www.eaaev.org
EV Finder • www.evfinder.com
EV Tradin' Post • www.austinev.org/evtradinpost

For more information on used EVs, see "Finding & Buying a Used Electric Vehicle," in HP119.

Operating Costs

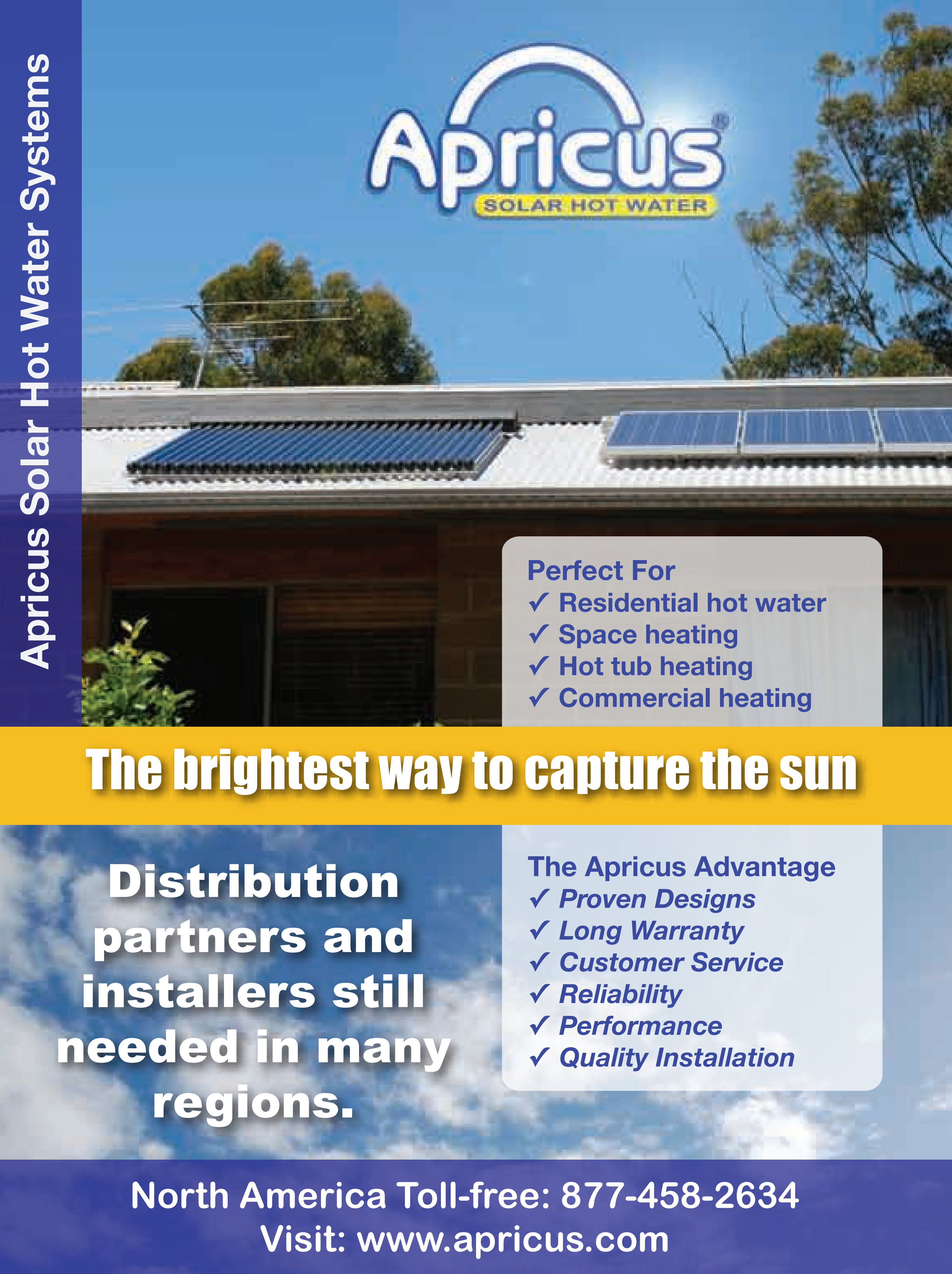
The average price of a gallon of regular unleaded gasoline ranged from $3.08 to $4.05 during the previous year and, while it takes a dip now and then, the overall trend has been an upward one. EVs offer you an opportunity to save money on fuel costs and declare your independence from oil by plugging in—instead of filling up at the pump. Your savings will largely depend on the source of your electricity—some folks even charge their EVs with homemade electricity from their own RE systems (see "EVs & the Environment" sidebar).

The cost of replacing the batteries every few years adds up quickly—they're not cheap. You could spend $1,500 to $3,000 on new ones every few years. That may seem like a lot, but remember that you're saving quite a bit of money on repairs and fuel. One visit to the repair shop to replace a timing belt on a gasoline-fueled vehicle can cost between $500 and $2,500. Even with the regular expense of battery replacement, an EV still seems to come out ahead. With ever-increasing gasoline prices, it's a safe bet that an EV will save you money over the long haul.

Access

Mark E. Hazen (mail@evhelp.com) converted his Chevy S10 pickup truck to an EV and created www.evhelp.com to assist others with their conversions. He is also the author of *Alternative Energy: An Introduction to Alternative and Renewable Energy Sources*.

Electric Auto Association • www.eaaev.org • Listings of local EV groups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A Beginner's Guide to Tower Climbing Safety

by Ian Woofenden

Ian Woofenden (5)

Left: The height of the towers compounds the dangers of installing and maintaining wind turbines. Above: Zander Woofenden demonstrates leaning out in a working position. Note that he is still clipped into the safety cable.

"Tower climbing remains the most dangerous job in America," according to the U.S. Occupational Safety and Health Administration (OSHA). Fatalities for all types of tower work per 100,000 workers in 2006 were 184, compared to 88 for pilots, 37 for farmers, 35 for utility-line workers, and 34 for roofers.

Comprehensive renewable energy industry statistics are not available. But journalist Paul Gipe—the author of several books on wind power—has informally maintained records of wind energy deaths. By his count, 32 deaths occurred between 1975 and 2006, only three of which involved home-scale wind-electric systems. These numbers may seem inconsequential until you consider the small size of the wind power industry, the few hundred people who work on towers, and above all, the tremendous loss for the families of those men and women.

Climbing towers is serious business, and accidents can and will happen. The sad but true reality is that most tower accidents are not caused by nature or the result of faulty equipment, but are the result of human error—lack of proper training and preparation, improper use of or lack of safety equipment, poor communication, or plain old carelessness.

You'll want to gain knowledge and experience through study, consultation with seasoned climbers, and cautious practice. Workshops hosted by safety gear manufacturers are another great resource. This article provides the fundamentals to get you started, but you'll gain most of your expertise by carefully practicing on the job. Climbing towers can be highly rewarding work. If you understand the hazards and practice safe climbing techniques, you can enjoy a lengthy, secure career "up tower."

Hazards

Home-scale wind generator towers pose a variety of hazards. First and foremost is the fall hazard (all other hazards are compounded by the fact that you're working well above the ground). Properly sited and installed wind generators are on towers from 60 to 200 feet high (or more). Not only is there the danger of falling but also the risk of injuring others or damaging equipment by dropping tools or parts.

Gravity-caused accidents are only one of the many hazards faced by tower climbers. Since wind turbines can produce high-voltage electricity, and the systems can be connected to the utility grid, there is also the risk of shock and electrocution. Turbines are rotating machines, and the grisly fact is that utility-scale wind service people have been killed by being dragged into the equipment.

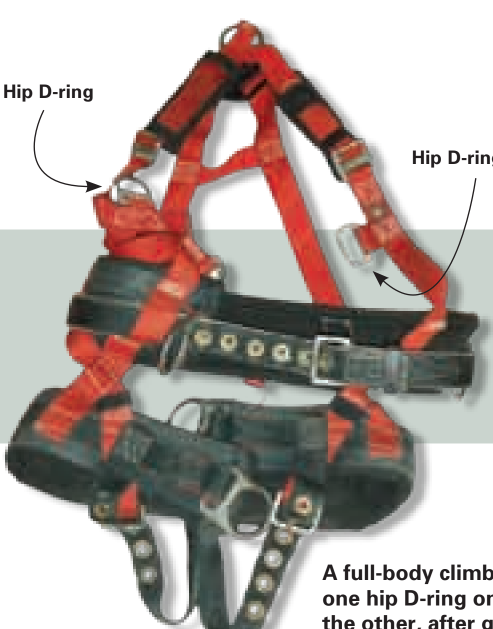
Weather is another frequent hazard. Climbing in rainy or icy conditions or during extremely cold or hot temperatures increases the danger, often to the point of being unsafe. The greatest danger lies in the unexpected—a lighting storm or wind-driven rain that sneaks up on you. When it comes to weather, common sense is your best defense. Beginning climbers routinely underestimate how much more severe the wind will be when they climb above nearby obstructions, and often find themselves unprepared and underdressed for the higher winds and colder temperatures aloft. When in doubt, err on the side of caution.

Other hazards stem from live distractions, such as bees and hornets, animals on the ground, and other climbers. Noise from nearby equipment can be hazardous as well, primarily because it impairs communication. A smart climber assesses the potential hazards before climbing and prepares for them. Discussing the hazards with your climbing partners and ground crew can help minimize the risk.

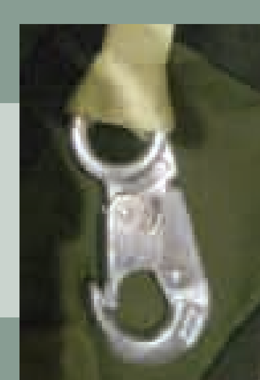
Equipment

To do tower work safely, you need the right gear. A quality harness is crucial. For maximum safety, a full-body harness with hip, seat, chest, and back D-rings is the preferred choice among professionals. It's impossible to fall out of a properly fitted full-body harness. The same cannot be said of lineman's belts or waist and seat harnesses.

Lanyards allow you to attach yourself to the tower in a number of ways. I like to carry at least two adjustable lanyards for positioning. These allow me to clip in and get comfortable



A full-body climber's harness. A carabiner attaches to one hip D-ring on the harness and the locking clip to the other, after going through or around the tower.



Left: An adjustable lanyard for fall safety and positioning on towers.

Above: A double-locking lanyard clip.

Left & middle: Examples of pulleys mounted on carabiners. These tools can be used for hauling gear up the tower or for emergency descents.

A Lad-Saf fall-arresting device attached to a cable that's permanently mounted on the tower.

right where I need to work. I also carry a short-strap lanyard attached to my seat D-rings. This comes in handy when I need a quick rest on the tower, allowing me to sit down and relax. Other climbers also use split lanyards, with one attachment to the harness and two lanyard legs with clips. These are commonly used as fall-safety devices on scaffolding and roofs, and some tower climbers use them as well. All lanyard clips should be double-locking or better.

When ascending and descending the main portion of a tower, you should be attached to a safety cable or line with a fall-arresting device such as a rope or cable grab. Lad-Saf is a common model. For some tower projects, you will be able to do the entire job while connected to this cable. These fall-arrest devices are meant for fall safety, not positioning—so you should carry and use lanyards to secure yourself into work positioning. You may need to detach yourself from the safety cable at the tower top, but you should *not* do it before you are securely tied in with at least one lanyard.

Always inspect the tower and system from the ground before attempting a climb.

Ian Woofenden (4)

Carabiners (or "beeners") are loops of steel or aluminum with locking gates. For tower climbing, all beeners should be at least double-locking. They are widely used for attaching fall-arrest devices, lanyards, tools, and additional gear to your harness and other places, like the tower. They are handy for any number of uses, so you won't regret hauling some extras on the side D-rings of your harness.

Descending devices and pulleys can be used for rapid descent in emergencies, or just for reducing the workout of climbing up and down the tower. You must be familiar with rigging these devices, and understand how to attach pulleys and lines to the tower and to yourself.

The proper attire—steel-shank work boots, heavy pants and shirt, gripping gloves, and a protective hat—is key for safe climbing. Also recommended are mesh goggles, which act as sunglasses while protecting your eyes from airborne debris. Plan ahead for the weather, dressing in layers that can be unzipped if it gets too hot. Carrying a closeable bag with extra gloves, a warm hat, an additional wind breaker, water, snacks, and other such items will make you that much more comfortable while you work—and therefore, that much more focused on your safety.

Having a first-aid kit on site—and knowing how to use it—is a must. While you don't need to be prepared for surgery, don't underestimate the value of basics like bandages for abrasions and blisters, and water for flushing eyes.

Groundwork

Before you climb, inspect your equipment. Look for wear or damage in your gear, and check that all beeners, clips, and other movable devices are functioning properly. Because another set of eyes never hurts when it comes to safety, have a climbing partner examine your harness and other gear before you climb—just in case anything is amiss.

In addition to a gear inspection and hazard assessment, perform a full inspection of the tower and system from the ground. If it's a guyed tower, inspect where the anchors come out of the ground and all attachments. Your life depends on the tower, so you want to discover any problems before you go

Open the Lines: Communicating in the Field

Good communication is important in any job, but when you're working high above ground, it can be a matter of life or death. Before you head "up tower," here are the keys to effective tower-climbing communication.

BABY TALK. I like to tell students to speak "baby talk"—tell your working partner everything you're going to do before you do it. Accidentally knocking someone in the nose with your elbow on the ground might hurt. On a tower, it could lead to a serious accident. Slow down and take time to talk through what you're going to do.

HAND SIGNALS. Communicating with the ground crew is vital to safe tower work. On a calm day at a quiet site or on shorter towers, shouting and hand signals get the job done. Before you head up the tower, review your signals with your ground crew, so there's no confusion. Good hand signals are simple and easily recognizable. For instance, a common signal for "stop" is to hold your arm straight out with a clenched fist. At noisy sites or on high towers, radios may become necessary, since it can be difficult to communicate by voice or hand signals.

WALKIE-TALKIES. As a backup to hand signals, most climbers also carry a walkie-talkie or voice-activated radio. These can ease strained voices and strained relations with the ground crew. Shouting from the top of a 150-foot tower can be difficult, especially if the ground crew is engaged with other tasks, or if there is other noise. Often I'll leave my radio in my pocket unless I need to give detailed instructions. That way I can hear

Shawn Schreiner

my ground crew talking to me and answer with a shout or hand signal—without having to interrupt my work to dig out the radio. Sometimes wind noise makes radio communication difficult, so it's important to know hand signals as a backup.

CELL PHONES. Having a cell phone on a tower can really save time and trouble. Many times I've talked with a turbine manufacturer or a colleague from the tower top when I had a problem and needed advice. An earpiece allows me to start the call, put my phone away, and keep both hands free to do work. A hand strap on your radios or cell-phone case may keep them from taking a dive. Voice-activated radios with headsets are a possible option in the right situation.

aloft. Broken or deteriorating gear should be replaced before you climb. Inspect the tower at the foundation, and re-tension guy wires and all bolts and cable attachments to manufacturers' specifications before you ascend and as you climb.

Use binoculars to look over the machine and tower top, and ask the system owners or operators about any recent issues. *Then* make a plan with your crew, specifically outlining the work you will do on the tower and in what order. As you make this list, think about what tools and parts you need. Planning ahead will make the job run more smoothly and limit the number of trips up and down the tower. Finally, practice and review all techniques at ground level first before climbing, especially if it's your first time—or if it's been a long time since you've been "up tower."

Ground Crew

Your ground crew is your connection with terra firma—don't work without them! Make the most of your ground crew so you can dedicate your time and energy to the work on the tower. With a pulley and service line, the ground crew can do all the raising and lowering of tools, parts, or even the whole turbine, if necessary. Trying to do this work from the tower top is exhausting, and can become a safety hazard.

I prefer a dedicated service line in a loop between two pulleys—one at the tower top and one at the tower base. In addition, the ground crew may be managing the tails of your safety lines, as well as taglines—lines dangling from equipment—for guiding gear up the tower. It's best if these workers are familiar with tower work—experienced climbers make great crew members.

Working with a crane adds another layer of safety concerns. You're dealing with a loud, powerful piece of equipment, often in tight quarters. A good crane operator can not only make your job easier but also keep you alive. Talk with your crane operator about the working plan, the limits of the equipment, and safety issues. Carefully assess the crane rigging and methods when lifting towers and turbines. Typically, heavy webbing slings are attached with large, locked shackles.

Agree on hand signals to use with the crane operator and designate *one* person from the crew to direct the crane. Above all, don't be in a rush. Cranes are expensive by the hour—but cheap compared to lives. Everyone's number-one priority should be getting the job done safely.

Technique

Getting up and down a tower safely and efficiently takes some finesse. The key is to climb primarily with your legs and not overuse your arms. You'll need both, of course, but your legs should take the bigger part of the workout as you make

your way up the tower. Many times novice climbers will find they have aching arms once they return to the ground. Your legs are better equipped to do this job, so *push* your way up the tower—don't pull.

Find an easy stance on the tower at a comfortable distance from the ladder or rungs. Don't hug yourself tight to the tower, or again, you'll end up with sore arms by the time you get back down. Step slowly and carefully up and down, watching as you make each contact with feet and hands, and maintaining two, if not three, points of contact at any time.

Rest when needed. Leave the macho sentiments behind and take a breather at regular intervals. I like to stop at least twice when climbing the 165-foot towers near my home. I strap in, enjoy the view, and take a swig from my water bottle.

Climbing is physical work. If you're not in shape for it, you'll feel it—no matter how you climb. Take it easy and build up to it gradually. It's a developed skill, and your muscles also need time to develop. Get plenty of rest the night before you climb, and eat a good breakfast. I once fainted on a tower from a potentially lethal combination—not enough sleep, not enough food and water, and not enough warmth. After 25 years climbing towers, I should have known better. I was lucky, but I learned a hard lesson. Don't make the same mistake—be prepared and know your limits.

100% Fall Protection

Make sure you are attached to the tower by at least one means at *all* times. I prefer to be attached twice or more, though I settle for one secure method when I'm moving on a tower. As soon as I stop to rest or work, I add another attachment. If the tower you're working on is equipped with a cable, use an appropriate fall-arrest device. Rope can also be used for the fall-arrest line, with a rope grab or an appropriate sliding knot (such as a Prusik knot or a Blake's hitch that arborists rappel on).

After you've moved up the tower to the level where you'll be working, you may need to disconnect from the safety cable or rope. *First* connect one or more lanyards securely to the tower. On large, freestanding towers, you may need to traverse across angled braces. Keep *at least* one attachment to the tower at all times—and watch carefully when detaching and reattaching your lanyards. Use your eyes, not just your ears, to assure yourself that they are properly clipped into your harness and the tower.

Once you're in position to work, adjust your lanyards so that you can stand and sit without holding on with your hands. Get comfortable. Rig a lanyard that will hold you by your seat D-rings, so you can sit at least some of the time. If you have to work over a wide area on the tower (horizontal or vertical), rig a line well above you that gives you the latitude to move, and use positioning lanyards to hold you in the specific places you're working.

Use tool bags with closures—rope bags from arborist supply houses are excellent. Attach small cords on major tools so they can be easily clipped to your harness, the tower, or your tool bag with beeners. One dropped wrench could be lethal for one of your ground crew.

When Problems Occur

Accidents can happen on any job. When you're high up a tower, even a minor accident or illness can be serious. Good planning and preparation are key to handling any unexpected accidents and emergencies that may arise. In addition to basic "up tower" and "on the ground" first aid, you will need to establish and practice a plan for removing an unconscious or injured tower climber.

The best tower rescue is self-rescue. If a climber is ill or injured but can get down the tower, assist him or her in getting down. If that isn't possible, quickly get the rigging together to lower the injured person to the ground. Call 911, but don't wait for them or expect them to remove your co-worker from the tower—you'll have to do it.

There are many descending devices and methods available. Setting a pulley and line and letting your ground crew lower you and the injured person is one straightforward method, but it requires a line twice the height involved. Using a single fixed line and a descending device (such as a Fisk descender), you can rappel down the tower with the injured person suspended by the D-ring on the back of his or her harness.

Depending on the severity of the injury, you may not have a lot of time to get the injured person down. Don't let your haste lead to two injured people. Apply standard safety precautions, staying tied in 100% of the time, and use a backup system if possible.

When it's time to descend, take a breath and make a plan. Gather and secure all your tools. I frequently use a service line on a pulley to raise and lower tools and gear to the tower crew, saving the work and inconvenience of hauling tools up and down on their belts or on a line.

If you had to get off the safety cable or rope, move back to it and reattach yourself. Double-check your fall-arrest device before detaching your lanyards. Climb down the tower slowly and deliberately—watch each foot find its place on each rung or step. You're often coming down the tower in the late afternoon or early evening, which is "accident time" on construction sites. Don't get sloppy. Pay attention until both feet are back on solid ground.

Common Sense

The most important safety device you have is on your shoulders—use your head! Above all, you must have two critical qualities—common sense and good communication. No amount of fancy equipment or paperwork will help you as much as those two traits. By thinking through your game plan and communicating it to your crew and climbing partners, you can avoid most tower accidents and enjoy a long, fulfilling career "up tower."

Access

Ian Woofenden (ian.woofenden@homepower.com) has logged several miles up and down towers over the last 25 years, and lives to tell the tales.

Safeguard Your RE Investment

FINDING A POLICY THAT WORKS FOR *YOUR* SYSTEM

by Lisa Cohn

In 2004, after their annual homeowner's insurance policy came up for renewal, Kathy Kenworthy and her husband, Paul Barale, started shopping for more affordable coverage for their 1920s-era home in Oakland, California. After requesting quotes from several insurance companies and comparing rates, they applied for a policy from a full-service insurance provider based in Rhode Island. Their application was approved, and their policy went into effect immediately. Easy enough—or so they thought.

Courtesy www.brookssolar.com

The policy stated that the structure and its contents were covered in the event of damage, theft, and other losses, so the couple assumed the coverage applied to the 3.4 kW, roof-mounted solar-electric system that they'd installed years earlier.

It never occurred to the couple that their preference for renewable energy would be a liability in the eyes of the insurance company. "Since the insurance company didn't ask us whether we had solar panels, we never thought of them as anything but integral parts of our house," Kenworthy says. "You don't insure your roof or your back deck separately. We didn't realize that solar panels might be different."

The couple was shocked when a notice of cancellation arrived in the mail a few days after an agent photographed the house for the company's policy records. The insurance company decided to terminate the policy, claiming that the home's PV modules and wood-burning stove were "too risky."

"Subsequent communications made it clear that this insurance company didn't understand how a PV system works. They were concerned about flooding and water damage to our house from our modules," Kenworthy says. "They also expressed concerns that the modules could cause a fire if they got too hot or that the modules might be damaged by hailstones. In Oakland, hailstones are pretty rare."

The company eventually offered to continue the couple's coverage, but only if they paid an additional $1,000 annually. Ultimately, Kenworthy and Barale took their business elsewhere.

Courtesy Jim White

This array was destroyed in a freakish wind storm.

The Fear Factor

Kenworthy and Barale are not alone in their frustration. Jumping through hoops and paying expensive premiums is a familiar story for homeowners with RE systems. Though the process is getting easier as renewable energy becomes more familiar and mainstream, some insurance providers still use RE systems as grounds for charging higher premiums or denying coverage.

"It's a case of the insurance companies being afraid of the unknown," says Jerry Caldwell, an assistant PV designer for SunPower Corporation in San Jose, California. "A PV system is like any other appliance you might put on a home. As long as the components and installation are to code, insurance companies should not feel at liberty to discriminate."

Bob Hartwig, president of the Insurance Information Institute in New York City, attributes the higher premiums to the added value of the home. "Having a renewable energy system on your home adds value that drives up the premium because the value of the house—the cost of rebuilding the home and replacing the system—is greater. It's no different than when insurers charge higher premiums for a finished basement or an art collection," he says.

He adds that it may take smaller insurance companies more time to adapt to the changing marketplace. "Some companies simply don't have the staff or resources to get up to speed on the latest technologies," Hartwig says.

Risky Business

The insurance companies aren't the only ones to blame for higher premiums. Utilities once required homeowners connecting to the grid to purchase extra liability insurance. The action helped falsely validate the notion that RE systems are "risky business" and gave insurance companies the justification they needed for higher premiums.

A paper presented at the June 2000 American Solar Energy Society Conference took aim at the risk stigma attached to RE systems, stating that "utility-imposed insurance requirements beyond typical homeowner's liability policies create unnecessary costs that discourage customers from investing in grid-connected PV systems." The authors—Robert K. Harmon and Thomas J. Starrs of Evergreen Energy LLC, in Vashon, Washington—found that the risks to utilities or third parties from grid-connected systems are very small.

Homeowner's insurance: An insurance policy that protects homeowners from *casualty* (losses or damage to the home and its contents) and *liability* (damages to other people or property).

Extreme winds blew two laminates right out of their frames on this pole-mounted PV array.

Lexington is among a small group of insurance companies supporting renewable energy. In March, the company began offering an "Eco-Homeowner" option that provides additional coverage for homeowners who generate their own power using grid-tied geothermal, solar-electric, or wind systems. When paired with Lexington's standard homeowner policy, the option—which usually accounts for 2% to 3% of the policy's premium—provides comprehensive protection against damage, theft, and other risks associated with on-site power generation, including damage to the utility grid and equipment replacement. The option also doubles the limits of a typical homeowner policy for eco-landscaping, such as trees or shrubs planted to shade the home.

If a system is damaged by a storm or other "peril," Lexington will pay the expenses for inspection, reconnection, and permits needed to get the system back online, as well as the cost of replacement power until the system is replaced or repaired to manufacturer's specifications. The homeowner is also reimbursed for any power-generation income lost while the system is down.

"Homes with solar systems, wind systems, and green features are more self-sustaining and energy efficient overall," says Jason Cassee, director of marketing for personal insurance for Fireman's Fund Insurance in Novato, California. "They offer benefits to homeowners from a financial perspective and to us from a risk-management perspective."

This summer, Fireman's Fund launched a program that offers a 5% discount off its premium to owners of Leadership in Energy and Environmental Design (LEED)-certified homes.

The vast majority of net-metering laws now prohibit the call for extra liability requirements from the utilities. However, because of the potential for higher insurance rates, RE dealers, installers, and organizations commonly advise homeowners to budget for higher premiums over the life of the system. "Some insurance companies and agents may be unwilling to insure your PV system," warns the Energy Center of Wisconsin on its Web site. "Or, they may provide insurance only if liability levels are increased. This can cost you several hundred dollars per year."

Industry Innovators

The good news is that homeowners may soon have more RE-friendly insurance options. Some forward-thinking providers are rewarding homeowners with credits and cost reductions for their Earth-friendly energy choices.

"Homeowners generating their own power are at the leading edge of the environmental sustainability trend and need leading-edge insurance coverage for their unique exposures," says David Valzania, a vice president at Lexington Insurance Company, a Massachusetts-based member of the American International Group.

Murphy's Law of Liability

With any luck, you may never need to file a claim with your homeowner's insurance. But consider what would happen if your wind turbine fell on your neighbor's property, damaging their house or worse yet, causing bodily injury.

"A tower crashing onto a neighbor's fence wouldn't be much different than a tree crashing onto a neighbor's fence," says Jason Cassee, a Fireman's Fund Insurance representative. "You'd be held liable for the damage, and the insurance company would pay up to your policy's liability limit. The rest of the cost would fall to you."

When it comes to liability insurance, it's generally best to prepare for the worst and hope for the best. Read through your policy carefully, and understand your liability limits and coverage. Then, look at the big picture—your system, its location, and the potential for liability issues.

Your piece of mind might be worth the added expense of upgrading your liability limit or buying an additional liability policy. Remember, preparing for the proverbial rainy day may help you enjoy the sunshine—and wind—all the more in the meantime.

Warranties: Another Kind of Protection

In addition to understanding what your insurance does and does not cover, it's a good idea to understand what your warranties cover—and for how long.

"Warranties cover problems with either work that the installer did or equipment from the manufacturer. Insurance is for everything else—acts of God, theft, vandalism, things you don't expect," explains Mike Hall, president of Borrego Solar Systems in Berkeley, California.

Warranties vary by state, manufacturer, installer, and the type of system. Most RE systems come standard with a one-, two-, or five-year warranty on workmanship and parts. Some installers offer extended warranties for an added cost.

PV consultant Joel Davidson advises people to shop for warranties like they would for insurance. "Warranties have become fairly standardized, but there are better and worse ones out there," he says. "It's important to ask questions and do your research from the beginning."

Most PV manufacturers guarantee that their modules will produce 80% of their initial production rating after 20 years. Wind turbines and their controllers usually come with a two-year warranty, but the expected lifetime of most turbines is 20 years. Inverters for both wind and solar-electric systems normally have two- or five-year warranties. In general, glazed collectors for solar hot water systems come with five- or 10-year limited warranties, while unglazed collectors—typically used for swimming pool heating—come with 10-year or limited lifetime warranties.

Many states that offer RE incentives and rebates require PV installers to offer longer warranties on equipment. In California, a 10-year warranty is mandatory, largely because the state wants to ensure that it gets a good return on its subsidies.

"Warranties have helped the RE energy movement grow. They were designed to instill confidence and ensure that the system is high quality," Davidson says. "The most important step when dealing with warranties is to choose your installer wisely. You need to work with a reputable and experienced installer who understands the warranty requirements for the incentives and can help you enforce your equipment warranties if a problem arises."

Even if you have homeowner's insurance that would cover a repair or replacement, it is best to rely on your warranty as much as possible. Only involve your insurance company when absolutely necessary—filing an insurance claim may result in higher premiums down the line, but taking advantage of your warranty is your right and does not cost a thing.

To start, the program will be available in 15 states—including Arizona, Illinois, Oregon, and Washington—according to Cassee. Although renewable energy systems alone will not meet the criteria for this benefit, RE systems are part of a package of features that meets LEED requirements for residences and qualifies a home for the discount.

The company also introduced an "Equipment Breakdown" option that pays self-generators up to $25,000 for any lost income and the cost of buying replacement power when a system is damaged by events like fires, hailstorms, or falling tree limbs. The extra cost of this option is about $70 per year on a $1 million home.

Both companies are bucking the industry norm that says "less is more" when rebuilding a home after a loss. Lexington offers an "Upgrade to Green" provision that allows homeowners to rebuild their homes to energy-efficiency standards, while another new provision from Fireman's Fund allows homeowners to rebuild a conventional house to LEED-certified standards.

The Best Policy

Some homeowners would rather not haggle with insurance companies or risk higher premiums. They skirt the issue by not volunteering information that the home has an RE system and believe that what the insurance company doesn't know won't hurt it. Not only is this approach illegal and unethical, it's far from shrewd since the insurance company could ultimately deny future claims based on disclosure issues.

One loose bolt sent this direct-drive Jacobs wind turbine to the ground. The homeowner's insurance policy covered the turbine replacement.

Joel Davidson, a PV consultant and coauthor of *The New Solar Electric Home*, recommends the direct approach. "PV professionals and RE users have to explain their systems to people in the same way that a doctor explains a procedure to patients. You must educate people to get their comfort level up," Davidson says. "Through knowledge, there is no fear."

In 1998, he and his wife, Fran Orner, took the time to educate their agent and insurance company, Oregon Mutual Insurance, about their plan to install a 2.44 kW solar-electric system on their home in Culver City, California. "We explained that we were installing a system with UL-listed equipment that is approved by the California Energy Commission, fully warranted by the installer and manufacturer, and exempt from property taxes," he says. "They asked us to send more information, so we did. A little patience and education—that's all it took to get them in the comfort zone."

Even though the system was among some of the earliest grid-connected systems installed in the United States, Oregon Mutual agreed to the idea. "Once they understood what they were dealing with, they gave us the okay to proceed and only raised our premium slightly—a few bucks, nothing major," Davidson says.

A Growing Niche

Not everyone may be as lucky as the Davidson–Orner family. Homeowners in California and other RE-friendly states may fare better than others. Regardless of the potential for higher premiums, honesty is still the best policy. Homeowners should contact their insurance provider and shop around.

At first glance, the market for "green" homeowner's insurance seems rather bleak, especially since the leading providers have been slow to expand into this market. Neither Allstate Insurance Company nor State Farm Insurance, for example, currently offer any discounts, incentives, or special policies for homes with RE systems or other eco-friendly technologies, according to their representatives. Together, the two companies hold one-third of the homeowner's insurance policies in the United States.

By being up-front and proactive, homeowners can raise awareness about the inequity and help cultivate demand for new insurance products. "The insurance industry has a long history of adapting to new technologies," Hartwig says. "When homes first got electricity back in the day, it was a novel thing too. Not all insurers were willing to take on the risk, but eventually everyone did. The same was true of indoor plumbing, gas appliances, and countless other innovations. It will take some time, but the industry will come around."

Access

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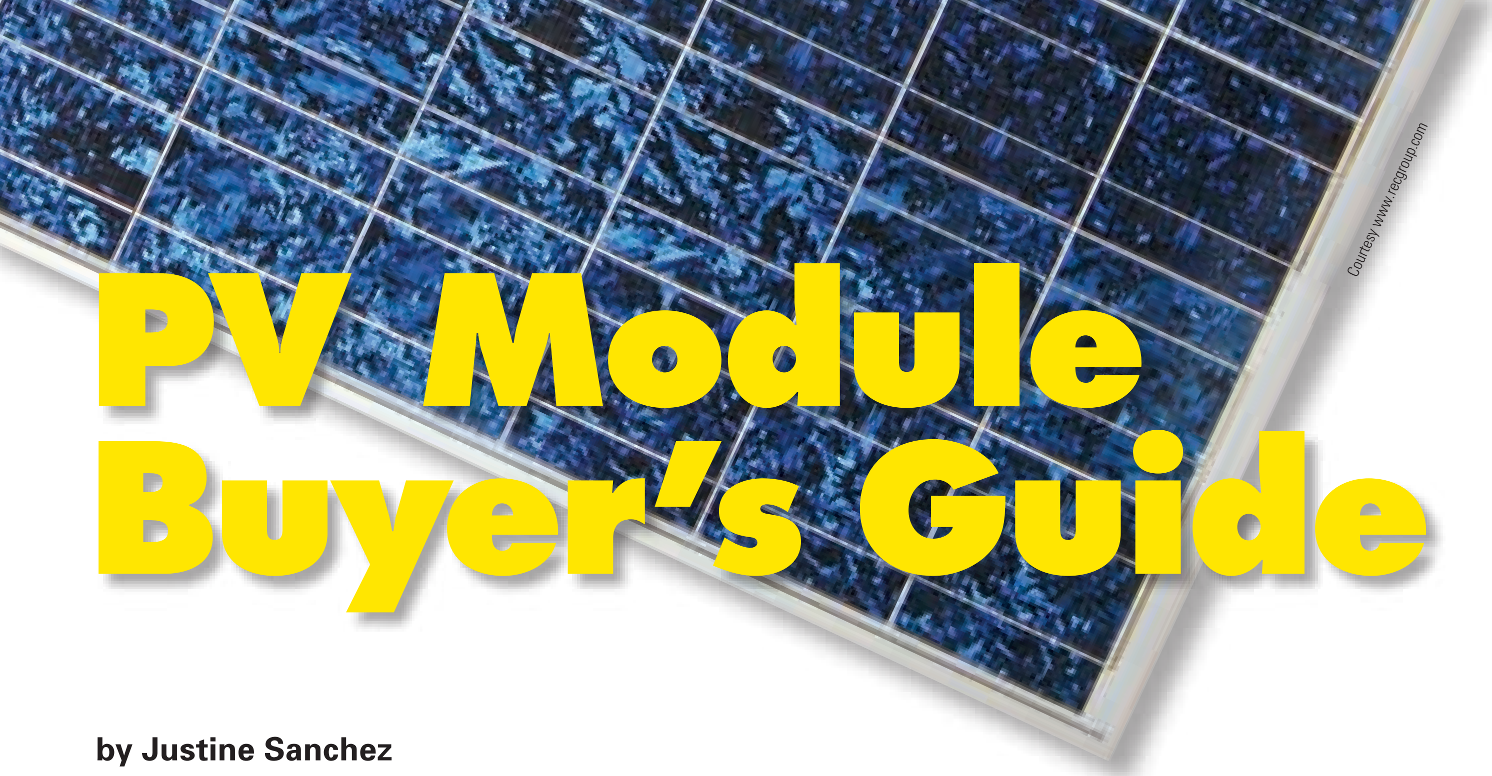


Courtesy www.recgroup.com

PV Module Buyer's Guide

by Justine Sanchez

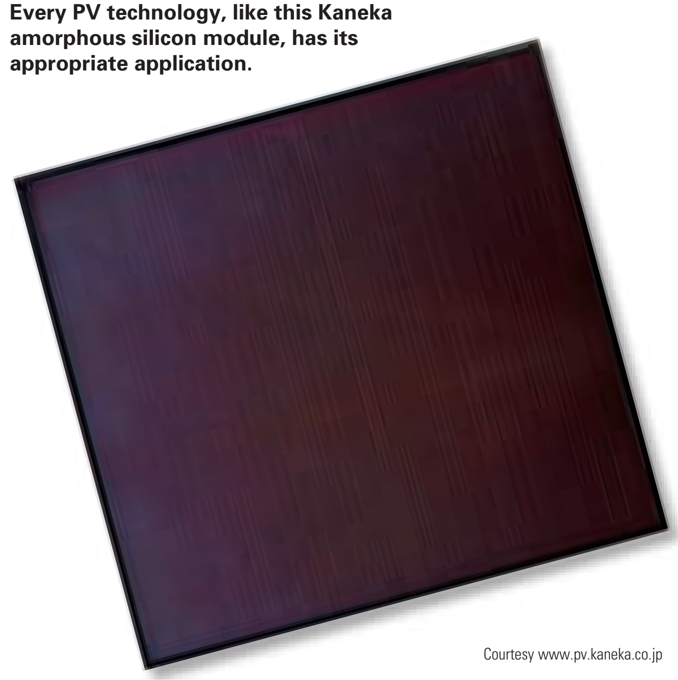
With a record-breaking 2,826 megawatts of PV installed worldwide in 2007, the global PV market experienced a 62% jump over 2006, according to a Marketbuzz report. In the United States, the PV market grew by an impressive 57%. New PV module manufacturers are coming online every month, while existing producers are building new manufacturing plants. This increased competition has given way to an overall increase in production and the introduction of a number of new modules to the market.

With all these new modules hitting the PV scene, figuring out which ones will be available to the residential PV market can be challenging (see "Commercial PV Trend" sidebar). In 2007, we published "The Perfect PV—*Home Power*'s 2007 Solar Electric Module Guide" (*HP121*). Now we've updated that guide with modules available as of September 2008.

How to Use This Guide

The table of PV modules on the following pages includes Underwriters Laboratories-listed crystalline modules that are 100 watts or larger (under standard test conditions, STC), and UL-listed thin-film options of 60 W and larger. Once you know the PV module options, you can match modules to your particular application. Understanding how to interpret PV module specifications will help you make the best choice to suit your PV system goals and help optimize performance over the system's lifetime. On the following pages, you'll find detailed descriptions of each specification and how it's related to PV system design parameters. (Note: In some instances, manufacturers may change specifications for a particular model.)

Every PV technology, like this Kaneka amorphous silicon module, has its appropriate application.



Courtesy www.pv.kaneka.co.jp

SPECIFICATIONS

Courtesy www.sanyo.com

New technologies, like these Sanyo HIT modules, blur the divisions between traditional silicon types and gain higher efficiencies.

Rated Power at STC (Watts)

Definition: Module power rating at STC—1,000 watts per square meter of solar irradiance at 25°C (77°F) cell temperature.

Importance: Because module power output depends on environmental conditions, such as irradiance and temperature, each module is tested at STC so that modules can be compared and rated on a level playing field. When less sunshine hits the module, less power is produced. Likewise, the hotter it gets, the less power your modules will produce.

STC references *cell* temperature—not ambient air temperature. As dark PV cells absorb radiant energy, their temperature increases and will be significantly higher than the ambient air temperature. For example, at an ambient air temperature of about 23°F, a PV cell's temperature will measure about 77°F—the temperature at which its power is rated. If the ambient air temperature is 77°F (and irradiance is about 1,000 W/m^2), module cell temperature will be about 131°F and power output will be reduced by about 15%. Other factors, like rated power tolerance (discussed below), can impact module power production as well.

Rated Power Tolerance (%)

Definition: The specified range within which a module will either overperform or underperform its rated power at STC.

Importance: Power tolerance is a much-debated module specification. Depending on the module, this specification can vary greatly—from as much as +10% to -9%. A 100 W module with a -9% power tolerance rating may only produce 91 W straight out of the box. With potential losses from high temperatures, it will likely produce even less than that.

Because modules are often rated in small increments, it is not uncommon for modules that fall under the lower power tolerance of the next model to be rated as a higher wattage module. Case in point: A module with a +/-5% power tolerance rating that produces 181 W during the factory testing process could be classified as a 190 W module, as opposed to a 180 W module. For maximum production, look for modules with a small negative (or positive only) power tolerance.

Rated Power Per Square Foot (Watts)

Definition: Power output at STC, per square foot of module (not cell) area. This is calculated by dividing module rated power by the module's area in square feet. Also known as "power density."

Importance: The higher the power density, the less space that is needed to produce a certain amount of energy. With some of the newer-generation modules, power density values are higher due to increased module efficiency. The greatest variation in this specification is in comparing crystalline PV modules to thin-film modules. If space is tight for array placement, consider choosing modules with higher power densities, though more efficient modules can be more expensive. Choose modules with lower power densities, and you'll need more modules for the same amount of energy. That means more infrastructure (module mounts, hardware, etc.) and more installation time. (See "Solar-Electric Options—Crystalline vs. Thin-Film" in *HP127* for more information.)

Module Efficiency (%)

Definition: The ratio of output power to input power, or how efficiently a PV module uses the photons in sunlight to generate DC electricity.

Importance: If 1,000 W of sunlight hit 1 square meter of solar module and that solar module produces 100 W of power from that square meter, then it has an efficiency of 10%. Similar to power density, the higher the efficiency value, the more electricity generated in a given space.

Commercial PV Trend

While many new PV companies are manufacturing UL-listed modules, several will only sell directly to large commercial/industrial and power-plant PV projects. You might find these modules listed in inverter string-sizing programs and on the Go Solar (California Energy Commission) Web site from companies such as First Solar, Siliken, and Solon, but you will not be able to buy them from PV distributors or dealers.

The trend toward commercial-scale-only sales is particularly evident with thin-film producers. Although consumers may hear of rapid growth in thin-film technology and market share, many thin-film options are not available for residential applications. This guide excludes modules (crystalline or thin-film) that are **only** available to the commercial or industrial PV market.

Model	Rated Power at STC (W)	Tolerance (%)	Per Sq. Ft. (W)	Module Efficiency (%)	Module Dimensions Length (In.)	Width (In.)	Depth (In.)	Weight (Lbs.)	Series Fuse Rating (A)	Connector Type
BP Solar www.bpsolar.com										
BP 3115J	115	+/-3	10.5	11.3						
BP 3125J	125		11.4	12.3	59.4	26.5		26.6		J-box
SX 3140J	140		12.8	13.8						
SX 3165B	165	+/-9	12.2		62.7	31.1				
SX 3170 I			12.4	13.1	62.5	32.6				
BP 170 I	170	+/-5								
BP 170 B			12.6	13.5						
SX 3175B		+/-9	12.9		62.7	31.1				
BP 175 B	175			13.9				33.9		
BP 175 I			12.8		62.5	32.6				
BP 180 B, I	180		13.8	14.4		31.1	2.0		15	
BP 4175 B	175	+/-5	12.9	13.9	62.7					MC
BP 4175 I			12.8		62.5	32.6				
BP 4180 B	180		13.3	14.3	62.7	31.1				
BP 4180 I			13.1		62.5	32.6				
SX 3190 N, B	190		12.6	13.5						
SX 3195 N, B	195	+/-9	12.9	13.9						
SX 3200 B, W					66.1	33.0		37.8		
BP3200 B, W	200	+/-5	13.2	14.2						
BP3195 B, W										
BP3230 N	230	+/-3	12.8	13.8	65.6	39.4		42.7	20	
Canadian Solar Inc. www.csisolar.com										
CS5A-130	130		9.5	10.2						
CS5A-135	135		9.8	10.6						
CS5A-140	140		10.2	11.0						
CS5A-145	145		10.5	11.3						
CS5A-150	150		10.9	11.7						
CS5A-155	155		11.3	12.1						
CS5A-160	160		11.6	12.5	62.8	31.5		34.2		
CS5A-165	165		12.0	12.9						
CS5A-170	170		12.4	13.3						
CS5A-175	175		12.7	13.7						
CS5A-180	180		13.1	14.1					10	
CS5A-185	185		13.5	14.5						
CS5A-190	190		13.8	14.9						
CS5P-200	200		10.9	11.8						
CS5P-205	205	+/-3	11.2	12.1			1.6			MC4
CS5P-210	210		11.5	12.4						
CS5P-215	215		11.8	12.6						
CS5P-220	220		12.0	12.9	63.1	41.8		44.1		
CS5P-225	225		12.3	13.2						
CS5P-230	230		12.6	13.5						
CS5P-235	235		12.8	13.8						
CS5P-240	240		13.1	14.1						
CS6C-100	100		9.4	10.1						
CS6C-105	105		9.9	10.6						
CS6C-110	110		10.3	11.1						
CS6C-115	115		10.8	11.6	58.5	26.2		26.5	15	
CS6C-120	120		11.3	12.1						
CS6C-125	125		11.7	12.6						
CS6C-130	130		12.2	13.1						

Series Fuse Rating (Amps)

Definition: Current rating of a series fuse used to protect a module from overcurrent, under fault conditions.

Importance: Each module is rated to withstand a certain number of amps. Too many amps flowing through the module—perhaps backfed amps from paralleled modules or paralleled strings of modules—could damage the module if it's not protected by an overcurrent device rated at this specification. Backfeeding from other strings is most likely to exist if one series string of modules stops producing power due to shading or a damaged circuit. Because PV modules are current-limited, there are some cases where series fusing may not be needed. When there is only one module or string, there is nothing that can backfeed, and no series string fuse is needed. In the case of two series strings, if one string stops producing power and the other string backfeeds through it, still no fuse is needed because each module is designed to handle the current from one string. Some PV systems even allow for three strings or more with no series fuses. This is due to 690.9 Exception B of the *NEC* and is possible when the series fuse specification is substantially higher than the module's short-circuit current (Isc). When required, series fuses are located in either a combiner box or in some batteryless inverters.

Connector Type

Definition: Module output terminal or cable/connector configuration.

Importance: Most modules come with "plug and play"

Warranty: Materials (Yrs.)	Warranty: Power (Yrs.) 90%/80%	Cell Type	Cells In Series	Max. Power: Voltage (Vmp)	Max. Power: Current (Imp)	Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coeff. (%/°C)	Open-Circuit Voltage Temp. Coeff. (mV/°C)	Nominal Operating Cell Temp. (°C)
				17.10	6.70	21.8	7.50			
			36	17.40	7.20	22.0	8.10		-80	
				17.50	8.00		8.20			
				35.20	4.70	44.2	5.10			
		Multi		35.40	4.80	43.6	5.27			
			72	36.10	4.90	44.2	5.30		-160	
5	12/25					43.6	5.40	-0.47		47.0
		Mono		35.40	4.94		5.45			
				35.50	5.10		5.60			
				24.30	7.82	30.6	8.50			
				24.40	7.96	30.7	8.60			
		Multi	50	24.50	8.16	30.8	8.70		-111	
			60	29.20	7.90	36.4			-133	
				34.60	3.75	42.9	4.21		-150	
				34.70	3.89		4.35			
					4.03		4.49			
					4.17	43.0	4.63		-151	
				34.80	4.31	43.2	4.74			
					4.45	43.4	4.86		-152	
		Multi/ Mono	72	34.90	4.58	43.6	4.97		-153	
				35.20	4.69	43.8	5.08			
				35.50	4.79	44.1	5.19		-154	
				35.80	4.89	44.3	5.29		-155	
				36.10	4.99	44.5	5.40		-156	
				36.40	5.09	44.7	5.50			
				36.60	5.18	44.9	5.60		-157	
				46.40	4.31	57.4	4.78		-201	
2	10/25			46.50	4.41	57.6	4.86	-0.45	-202	45.0
				46.60	4.51	57.9	4.94		-203	
				46.70	4.61	58.1	5.02			
		Multi	96	46.90	4.69	58.4	5.10		-204	
				47.20	4.76	58.6	5.18		-205	
				47.50	4.84	58.8	5.25		-206	
				47.80	4.92	59.1	5.33		-207	
				48.10	4.99	59.3	5.40		-208	
					5.79	21.5	6.46		-75	
					6.08		6.74			
				17.30	6.36	21.6	7.01			
		Multi/ Mono	36		6.64		7.28		-76	
					6.92	21.7	7.52			
				17.40	7.20	21.8	7.75			
				17.50	7.43	22.0	7.96		-77	

weather-tight connectors to reduce installation time in the field. These are connectors such as Solarlok (manufactured by Tyco Electronics), and MC and MC4 (manufactured by Multi-Contact USA). Solarlok and MC4 are lockable connectors that require a tool for opening. Because so many PV systems installed today operate at high DC voltages, lockable connectors are being used on modules in accessible locations to prevent untrained persons from "unplugging" the modules, per *2008 NEC* Article 690.33(C). Due to this new code requirement, most PV manufacturers are updating their connectors to the locking type. Depending on how fast this change is reflected in the supply chain, connectors on a particular module may be an older style or lockable—so be sure to check.

Some manufacturers still offer modules with junction boxes (J-boxes). J-boxes allow the use of conduit in between modules, as raceways are required for PV source and output circuits (with a maximum system voltage greater than 30 volts) installed in readily accessible locations per *2008 NEC* Article 690.31(A). This approach is used to prevent an unqualified person from accessing array wiring.

Materials Warranty (Years)

Definition: A limited warranty on module materials and quality under normal application, installation, use, and service conditions.

Importance: For the modules listed in this guide, material warranties vary from 1 to 10 years. Most manufacturers offer full replacement or free servicing of a defective module.

	Rated Power			Module	Module Dimensions					
Model	at STC (W)	Tolerance (%)	Per Sq. Ft. (W)	Efficiency (%)	Length (In.)	Width (In.)	Depth (In.)	Weight (Lbs.)	Series Fuse Rating (A)	Connector Type
Canadian Solar Inc. (continued)										
CS6A-120	120		8.6	9.2						
CS6A-125	125		8.9	9.6						
CS6A-130	130		9.3	10.0						
CS6A-135	135		9.6	10.4						
CS6A-140	140		10.0	10.8						
CS6A-145	145		10.4	11.2						
CS6A-150	150		10.7	11.5						
CS6A-155	155		11.1	11.9	52.1			35.3		
CS6A-160	160		11.4	12.3						
CS6A-165	165		11.8	12.7		38.7				
CS6A-170	170		12.1	13.1						
CS6A-175	175		12.5	13.5						
CS6A-180	180		12.9	13.8						
CS6A-185	185		13.2	14.2						
CS6A-190	190		13.6	14.6						
CS6P-150	150	+/-3	8.7	9.3			1.6		15	MC4
CS6P-155	155		9.0	9.6						
CS6P-160	160		9.2	9.9				40.8		
CS6P-165	165		9.5	10.3						
CS6P-170	170		9.8	10.6						
CS6P-175	175		10.1	10.9						
CS6P-180	180		10.4	11.2						
CS6P-185	185		10.7	11.5						
CS6P-190	190		11.0	11.8	64.5					
CS6P-195	195		11.3	12.1						
CS6P-200	200		11.6	12.4		38.7		40.8		
CS6P-205	205		11.8	12.7						
CS6P-210	210		12.1	13.1						
CS6P-215	215		12.4	13.4						
CS6P-220	220		12.7	13.7						
CS6P-225	225		13.0	14.0						
CS6P-230	230		13.3	14.3						
Day4 Energy Inc. www.day4energy.com										
	160		11.5	12.4						
	165		11.8	12.7						
	170		12.2	13.1						
Day4 48 MC	175	+/-3.5	12.6	13.5	51.5	39.0	1.4	38.3	15	Solarlok
	180		12.9	13.9						
	185		13.3	14.3						
	190		13.6	14.7						
ET Solar Group www.etsolar.com										
ET-P654180	180		11.4	12.2						
ET-P654185	185		11.7	12.6						
ET-P654190	190		12.0	12.9						
ET-P654195	195		12.3	13.3	58.3			39.3		
ET-P654200	200		12.6	13.6						
ET-P654205	205		13.0	13.9						
ET-P654210	210		13.3	14.3						
ET-P654215	215		13.6	14.6						
ET-P672240	240	+/-3	11.5	12.4		39.1	2.0		12	Solarlok
ET-P672245	245		11.7	12.6						
ET-P672250	250		12.0	12.9						
ET-P672255	255		12.2	13.1						
ET-P672260	260		12.4	13.4	77.0			50.7		
ET-P672265	265		12.7	13.7						
ET-P672270	270		12.9	13.9						
ET-P672275	275		13.2	14.2						
ET-P672280	280		13.4	14.4						

Power Warranty (Years)

Definition: A limited warranty for module power output based on the minimum peak power rating (STC rating minus power tolerance percentage) of a given module.

Importance: The manufacturer guarantees that the module will provide a certain level of power for a period of time—at least 20 years. Most warranties are structured as a percentage of minimum peak power output within two different time frames—90% over the first 10 years and 80% for the next 10 years. For example, a 100 W module with a power tolerance of +/-5%, will carry a manufacturer guarantee that the module should produce at least 85.5 W (100 W x 0.95 power tolerance x 0.9) under STC for the first 10 years. For the next 10 years, the module should produce at least 76 W (100 W x 0.95 power tolerance x 0.8). Module replacement value provided by most power warranties is generally prorated according to how long the module has been in the field.

Warranty Materials (Yrs.)	Warranty Power (Yrs.) 90%/80%	Cell Type	Cells In Series	Max. Power Voltage (Vmp)	Max. Power Current (Imp)	Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coeff. (%/°C)	Open-Circuit Voltage Temp. Coeff. (mV/°C)	Nominal Operating Cell Temp. (°C)
2	10/25	Multi	48	22.90	5.24	28.5	5.89	-0.45	-100	45.0
					5.45	28.6	6.10			
				23.00	5.66		6.31			
					5.87	28.7	6.52			
					6.08		6.72			
					6.29	28.8	6.92		-101	
				23.10	6.50		7.12			
					6.71		7.32			
					6.92	28.9	7.51			
					7.13	29.0	7.69		-102	
				23.20	7.33	29.2	7.85			
				23.40	7.49	29.3	8.03		-103	
				23.60	7.62	29.4	8.20			
				24.00	7.71	29.5	8.37			
				24.20	7.84	29.6	8.54		-104	
			60	28.60	5.25	35.6	5.90		-125	
					5.42		6.08			
					5.59	35.7	6.26			
				28.70	5.76		6.45			
				28.70	5.93	35.8	6.62		-125	
					6.10	35.9	6.80		-126	
					6.26	35.9	6.98			
				28.80	6.43	36.0	7.16			
					6.60		7.33			
					6.76	36.1	7.51			
				28.90	6.93	36.2	7.68		-127	
					7.10		7.80			
					7.26	36.4	7.91			
				29.00	7.43	36.5	8.01		-128	
				29.30	7.52	36.6	8.09			
				29.50	7.63	36.7	8.19			
				29.80	7.71	36.8	8.34		-129	

Warranty Materials (Yrs.)	Warranty Power (Yrs.) 90%/80%	Cell Type	Cells In Series	Max. Power Voltage (Vmp)	Max. Power Current (Imp)	Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coeff. (%/°C)	Open-Circuit Voltage Temp. Coeff. (mV/°C)	Nominal Operating Cell Temp. (°C)
5	10/25	Multi	48	22.60	7.08	28.3	7.70	-0.48	-110	46.9
				22.95	7.19	28.6	7.80			
				23.04	7.38	28.8	7.90			
				23.40	7.48	29.2	8.05			
				23.70	7.60	29.4	8.10			
				23.82	7.77	29.5	8.20			
				24.00	7.92	29.7	8.30			

Warranty Materials (Yrs.)	Warranty Power (Yrs.) 90%/80%	Cell Type	Cells In Series	Max. Power Voltage (Vmp)	Max. Power Current (Imp)	Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coeff. (%/°C)	Open-Circuit Voltage Temp. Coeff. (mV/°C)	Nominal Operating Cell Temp. (°C)
5	25	Multi	54	26.45	6.81	32.4	7.60	-0.49	-112	45.3
				26.45	6.99	32.3	7.70			
				26.78	7.10	32.5	7.72			
				27.00	7.22	32.8	7.98		-113	
				27.21	7.36	32.7	7.86			
				27.30	7.50	32.8	8.10			
				27.54	7.63	32.8	8.30		-114	
					7.81	33.2	8.50		-115	
			72	34.95	6.88	43.9	7.63		-152	
					7.01		7.70			
				35.20	7.12		7.81			
					7.23		7.85			
				36.00	7.23	43.5	7.79		-150	
				36.40	7.28	43.6	7.90		-151	
					7.42					
				36.72	7.49	43.8	7.96			
					7.63		7.98			

Cell Type

Definition: The type of silicon that comprises a specific cell, based on the cell manufacturing process.

Importance: For the modules listed, there are four basic types—monocrystalline, multicrystalline, ribbon, and amorphous silicon (a-Si). Each cell type has pros and cons. Monocrystalline PV cells are the most expensive and energy-intensive to produce but usually yield the highest efficiencies. Though multicrystalline and ribbon silicon cells are slightly less energy intensive and less expensive to produce, these *cells* are slightly less efficient than monocrystalline cells. However, because both multi- and ribbon silicon modules leave fewer gaps on the module surface (due to square or rectangular cell shapes), these *modules* can often offer about the same power density as monocrystalline modules. Thin-film modules, such as those made from amorphous silicon cells, are the least expensive to produce and require the least amount of energy

Model	Rated Power at STC (W)	Rated Power Tolerance (%)	Rated Power Per Sq. Ft. (W)	Module Efficiency (%)	Module Dimensions Length (In.)	Module Dimensions Width (In.)	Module Dimensions Depth (In.)	Weight (Lbs.)	Series Fuse Rating (A)	Connector Type
Evergreen Solar www.evergreensolar.com										
ES-180	180	+3.5/-2	11.2	12.0	61.8	37.5	1.6	40.1	15	MC
ES-190	190	+2.5/- 2	11.8	12.7						
ES-195	195	+2.5/-0	12.1	13.1						
ES-A-200	200		11.8	12.7	65.0		1.8	41.0	20	
ES-A-205	205		12.1	13.1						
ES-A-210	210		12.4	13.4						
GE Energy www.gepower.com/solar										
GEPVp-200-MSA	200	+/-5	12.8	13.9	58.5	38.6	1.4	39.0	15	Solarlok
GEPVp-066-G	66		9.2	10.1		17.6	1.2	18.0		
Kaneka www.pv.kaneka.co.jp										
G-SA060	60	+10/-5	5.9	6.3	37.8	39.0	1.6	30.2	7	MC
Kyocera www.kyocerasolar.com										
KD130SX	130	+/-5	12.0	13.0	59.1	26.3	1.4	28.7	15	MC
KD135SX	135		12.5	13.5						
KD130GX	130		12.0	13.0						
KD135GX	135		12.5	13.5						
KD180GX	180		12.6	13.6	52.8	39.0		36.4		
KD205GX	205		12.8	13.8	59.1			40.8		
KD210GX	210		13.1	14.2						
Mitsubishi Electric www.mitsubishielectricsolar.com										
PV-UE115MF5N	115	+10 /- 5	10.6	11.4	58.9	26.5	1.8	29.8	15	MC
PV-UE120MF5N	120		11.1	11.9						
PV-UE125MF5N	125		11.5	12.4						
PV-UE130MF5N	130		12.0	12.9						
PV-UD175MF5	175	+/-3	11.8	12.7	65.3	32.8		37.0		
PV-UD180MF5	180		12.1	13.0						
PV-UD185MF5	185		12.4	13.4						
PV-UD190MF5	190		12.8	13.7						
REC Solar www.recgroup.com										
SCM210	210	+/-3	11.8	12.7	65.6	39.0	1.7	48.5	15	MC
SCM215	215		12.1	13.0						
SCM220	220		12.4	13.3						
SCM225	225		12.7	13.6						
SCM230	230		13.0	13.9						
Sanyo www.sanyo.com										
HIT Power 180	180	+10/-0	14.4	15.5	51.9	34.6	1.8	33.1	15	MC4
HIT Power 186	186		14.9	16.0						
HIT Power 190	190		15.2	16.4						
HIT Power 195	195		15.6	16.8						
HIT Power 200	200		16.0	17.2						
HIT Power 205	205		16.4	17.7						
HIT Double 180[a]	180		13.8[b] / 17.6[c]	14.8[b] / 19.0[d]	53.2	35.4	2.4	50.7		MC
HIT Double 186[a]	186		14.2[b] / 18.2[c]	15.3[b] / 19.6[d]						
HIT Double 190[a]	190		14.6[b] / 18.6[c]	15.7[b] / 20.0[d]						
HIT Double 195[a]	195		14.9[b] / 19.1[c]	16.1[b] / 20.5[d]						
HIT Double 200[a]	200		15.3[b] / 19.6[c]	16.5[b] / 21.1[d]						
Schott Solar www.us.schott.com										
ASE 250	250	+/-2	9.6	10.3	74.5	50.5	2.0	107.0	10	MC
ASE 260	260		10.0	10.7						
ASE 270	270		10.3	11.1						
ASE 280	280	+/-4	10.7	11.5					12	
ASE 290	290		11.1	11.9						
ASE 300	300		11.5	12.4						
ASE 310	310		11.9	12.8						

a) For bifacial modules, STC does not include power from the back face, which can be up to 30% more.
b) Values at STC (front face irradiance only).

and raw materials, but are the least efficient of the cell types. They require about twice as much space to produce the same power as mono-, multi-, or ribbon-silicon modules. Thin-film modules do have better shade tolerance and high-temperature performance but are often more expensive to install because of their lower power density.

Some manufacturers now offer a cell with a combination of cell types—Sanyo's "bifacial" HIT modules are composed of a monocrystalline cell and a thin layer of amorphous silicon material. In addition to generating power from the direct rays of the sun on the module face, this hybrid module can produce power

Warranty		Cell Type	Cells In Series	Max. Power		Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coeff. (%/°C)	Open-Circuit Voltage Temp. Coeff. (mV/°C)	Nominal Operating Cell Temp. (°C)
Materials (Yrs.)	Power (Yrs.) 90%/80%			Voltage (Vmp)	Current (Imp)					
5	10/25	Ribbon	54	25.90	6.95	32.6	7.78	-0.49	-112	45.9
				26.70	7.12	32.8	8.05		-113	
				27.10	7.20	32.9	8.15		-114	
			38	18.70	11.23	23.1	12.20	-0.45	-74	44.8
				18.40	11.15	22.8	12.10		-73	
				18.10	11.05	22.5	12.00		-72	
5	10/20	Multi	54	26.30	7.60	32.9	8.10	-0.50	-120	45.0
			18	9.00	7.40	10.9	8.20	-0.40	-30	
5	25	a-Si	N/A	67.00	0.90	91.8	1.19	-0.26	-285	45.0
1	20	Multi	36	17.70	7.35	22.1	8.06	-0.46	-80	49.0
					7.63		8.37			
					7.35		8.06			
					7.63		8.37			
			48	23.60		29.5	8.35		-106	
			54	26.60	7.71	33.2	8.36		-120	
					7.90		8.58			
1	10/25	Multi	36	17.10	6.75	21.5	7.60	-0.45	-74	47.5
				17.20	6.99	21.6	7.75			
				17.30	7.23	21.8	7.90		-75	
				17.40	7.47	21.9	8.05			
			50	23.90	7.32	30.2	7.93		-104	
				24.20	7.45	30.4	8.03		-105	
				24.40	7.58	30.6	8.13			
				24.70	7.71	30.8	8.23		-106	
5	10/25	Multi	60	28.20	7.50	36.1	8.10	-0.45	-104	47.5
				28.30	7.60	36.3				
				28.70	7.70	36.6	8.20			
				29.10		36.8	8.20			
				29.40	7.80	37.1	8.30			
5	20	Mono, a-Si	96	54.00	3.33	66.4	3.65	-0.33	-173	46.9
				54.40	3.42	67.0	3.71	-0.30	-168	
				54.80	3.47	67.5	3.75		-169	
				55.30	3.53	68.1	3.79		-170	
				55.80	3.59	68.7	3.83	-0.29	-172	
				56.70	3.62	68.8	3.84			
2				54.4[b] / 54.6[c]	3.31[b] / 4.21[c]	67.0[b] / 67.7[c]	3.62[b] / 4.71[c]	-0.30	-168	46.6
				54.8[b] / 55.1[c]	3.40[b] / 4.32[c]	67.5[b] / 68.2[c]	3.68[b] / 4.78[c]		-169	
				55.3[b] / 55.6[c]	3.44[b] / 4.37[c]	68.1[b] / 68.8[c]	3.70[b] / 4.81[c]		-170	
				55.8[b] / 56.1[c]	3.50[b] / 4.45[c]	68.7[b] / 69.5[c]	3.73[b] / 4.85[c]	-0.29	-172	
				56.2[b] / 56.5[c]	3.56[b] / 4.52[c]	68.8[b] / 69.6[c]	3.75[b] / 4.88[c]			

c) Values including a maximum 30% contribution in Isc from irradiance on the back face.
d) Efficiency for both faces, for approximate comparison to a single-faced module.

Materials (Yrs.)	Power (Yrs.) 90%/80%	Cell Type	Cells In Series	Vmp	Imp	Voc	Isc	Max. Power Temp. Coeff. (%/°C)	Open-Circuit Voltage Temp. Coeff. (mV/°C)	Nominal Operating Cell Temp. (°C)
1	20	Ribbon	108	48.50	5.15	60.0	5.90	-0.47	-208	45.0
				48.70	5.50					
				49.10			6.05			
				49.60	5.65	61.9	6.20		-214	
				50.10	5.80	62.5	6.40		-216	
				50.60	5.90	63.2	6.50		-219	
				51.10	6.10	63.8			-221	

from reflected light on its underside, increasing overall module efficiency.

Cells in Series

Definition: Number of individual PV cells wired in series, which determines the module design voltage.

Importance: Crystalline PV cells each operate at about 0.5 V. When cells are wired in series, the voltage of each cell is additive. For example, a module that has 36 cells in series has a maximum power voltage (Vmp) of about 18 V. Why 36? Historically, these modules—known as 12 V modules—were designed to push power into 12 V batteries. But to deliver the

Model	Rated Power at STC (W)	Rated Power Tolerance (%)	Rated Power Per Sq. Ft. (W)	Module Efficiency (%)	Module Dimensions Length (In.)	Module Dimensions Width (In.)	Module Dimensions Depth (In.)	Weight (Lbs.)	Series Fuse Rating (A)	Connector Type
Schüco www.schueco.com										
232 923	165	+/-5	11.1	11.9	65.3	32.8	1.8	37.5	15	MC
232 924	170		11.4	12.3						
256 695	175		11.8	12.7						
256 186	180		12.1	13.0						
SPV 200 SMAU-1	200	+/-3	12.7	14.2	58.3	38.9	1.9	37.9		Solarlok
SPV 210 SMAU-1	210		13.3	14.9						
S 310-PMU-2	310		10.7	11.5	84.7	49.3	3.7	108.0	10	MC
S 320-PMU-2	320		11.0	11.9						
S 330-PMU-2	330		11.4	12.2						
Sharp www.solar.sharpusa.com										
ND-130UJF	130	+10/-5	12.2	13.1	59.0	26.1	1.8	30.9	15	J-box
ND-N2ECUF	142		11.4	12.3	45.9	39.0		32.0		MC
NE-170U1	170		12.1	13.1	62.0	32.5		35.3	10	
NT-175U1	175		12.5	13.5						
ND-176U1Y	176		12.4	13.3	52.3	39.1	2.3	36.4	15	
ND-198U1F	198			13.4	58.7			39.6		
ND-216U1F	216		12.3	13.3	64.6		1.8	44.1		
ND-216U2										
ND-220U1F	220		12.5	13.5						
ND-220U2										
ND-224U1F	224		12.8	13.7						
ND-224U2										
ND-V230A1	230		13.1	14.1				44.0		
SolarWorld www.solarworld-usa.com										
Sunmodule SW 155	155	+/-3	11.0	11.9	63.4	31.9	1.3	33.0	15	MC
Sunmodule SW 165	165		11.7	12.7						
Sunmodule SW 175	175		12.4	13.4						
SunPower Corp. www.sunpowercorp.com										
SPR-210-BLK	210	+/-5	15.7	16.9	61.4	31.4	1.8	33.0	15	MC
SPR-215-WHT	215		16.1	17.3						
SPR-225-BLK	225		16.8	18.1					20	
SPR-230-WHT	230		17.2	18.5						
SPR-305-WHT	305		17.4	18.7		41.2		53.0	15	
Suntech Power www.suntech-power.com										
STP160-24/Ab-1	160	+/-3	11.6	12.5	62.2	31.8	1.4	34.2	15	MC
STP165-24/Ab-1	165		12.0	12.9						
STP170-24/Ab-1	170		12.4	13.3						
STP175-24/Ab-1	175		12.7	13.7						
STP180-24/Ab-1	180		13.1	14.1						
STP160S-24/Ab-1	160		11.6	12.5						
STP165S-24/Ab-1	165		12.0	12.9						
STP170S-24/Ab-1	170		12.4	13.3						
STP175S-24/Ab-1	175		12.7	13.7						
STP180S-24/Ab-1	180		13.1	14.1						
STP190-18/Ub-1	190		12.0	12.9	58.3	39.1		37.0	20	
STP200-18/Ub-1	200		12.6	13.6						
STP210-18/Ub-1	210		13.3	14.3						
STP190S-18/Ub-1	190		12.0	12.9						
STP200S-18/Ub-1	200		12.6	13.6						
STP210S-18/Ub-1	210		13.3	14.3						
STP190S-18/Ub-1	190		12.0	12.9						

12 V, they needed to have enough excess voltage (electrical pressure) to compensate for the voltage loss due to high-temperature conditions. Modules with 36 ("12 V") or 72 ("24 V") cells are designed for battery-charging applications.

Modules with other numbers of cells in series are intended for use in batteryless grid-tied systems. Grid-tied modules now combine a certain number of cells for the goal of maximizing power with grid-tied inverters and their maximum power point tracking (MPPT) capabilities. Due to the increased availability of step-down/MPPT battery charge controllers, grid-tied PV modules can also be used for battery charging, as long as they stay within the voltage limitations of the charge controller.

Maximum Power Voltage (Vmp)

Definition: The voltage generated by a PV module or array when exposed to sunlight and connected to a load—typically a batteryless inverter or a charge controller and battery.

Importance: Batteryless grid-tied inverters and MPPT charge controllers are built to track maximum power throughout the day, and the Vmp of each module and array, as well as array operating temperatures, must be considered when sizing an array to a particular inverter or controller. Increasing temperatures cause voltage to decrease; decreasing temperatures cause voltage to increase. Fortunately, series string-sizing programs

	Warranty Materials (Yrs.)	Warranty Power (Yrs.) 90%/80%	Cell Type	Cells In Series	Max. Power Voltage (Vmp)	Max. Power Current (Imp)	Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coeff. (%/°C)	Open-Circuit Voltage Temp. Coeff. (mV/°C)	Nominal Operating Cell Temp. (°C)
	5	12/25	Multi	50	23.40	7.06	29.7	7.73	-0.45	-102	46.2
					23.70	7.19	29.9	7.83		-103	46.3
					23.90	7.32	30.2	7.93		-104	
					24.20	7.45	30.4	8.03			
			Mono	54	25.38	7.89	33.5	8.24	-0.50	-111	43.0
					26.30	7.98	33.7	8.35		-112	
				144	72.30	4.30	88.1	4.65	-0.37	-292	46.0
						4.40		4.75			
					72.40	4.50	88.6	4.80		-294	
	1	25	Multi	36	17.40	7.50	21.9	8.20	-0.49	-72	47.5
				42	19.92	7.13	25.2	7.84		-91	
				72	34.80	4.90	43.2	5.47		-156	
			Mono		35.40	4.95	44.4	5.40		-160	
			Multi	48	23.42	7.52	29.3	8.22		-96	
				54	26.30		32.9	8.23		-108	
				60	28.90	7.48	36.5	8.10		-131	
					28.70	7.53	36.3	8.35			
					29.19	7.54	36.5	8.24		-120	
					29.28	7.66	36.6	8.33			
					30.30	7.60	37.0	8.24		-133	
	2	10/25	Mono	72	34.80	4.46	43.6	4.90	-0.47	-144	46.0
					35.30	4.68	44.0	5.10		-145	
					35.80	4.89	44.4	5.30		-147	
	10	25	Mono	72	40.00	5.25	47.7	5.75	-0.38	-137	50.5
					39.80	5.40	48.3	5.80			
					41.00	5.49	48.5	5.87		-133	
					41.00	5.61	48.7	5.99			
				96	54.70	5.58	64.2	5.96		-177	
	5	12/25	Multi	72	34.40	4.65	43.2	5.00	-0.47	-147	45.0
					34.80	4.74	43.6	5.04		-148	
					35.20	4.83	43.8	5.14		-149	
						4.95	44.2	5.20		-150	
					35.60	5.05	44.4	5.40		-151	
			Mono		34.40	4.65	43.2	5.00	-0.48	-147	
					34.80	4.74	43.6	5.04		-148	
					35.20	4.83	43.8	5.14		-149	
						4.95	44.2	5.20		-150	
					35.60	5.05	44.4	5.40		-151	
			Multi	54	26.00	7.31	33.0	7.89	-0.47	-112	
					26.20	7.63	33.4	8.12		-114	
					26.40	7.95	33.6	8.33		-114	
			Mono		26.20	7.25	33.2	7.84	-0.48	-113	
						7.63	33.6	8.10		-114	45.0
					26.40	7.95		8.33			
					26.20	7.25	33.2	7.84		-113	

for grid-tied inverters allow you to input both the high and low temperatures at your installation site, and calculate the correct number of modules in series to maximize system performance.

Maximum Power Current (Imp)

Definition: The maximum amperage produced by a module or array (under STC) when exposed to sunlight and connected to a load.

Importance: This specification is most commonly used in performing calculations for PV array disconnect labeling required by *NEC* Article 690.53(1), as the rated maximum power-point current for the array must be listed. Maximum power current is also used in array and charge controller sizing calculations for battery-based PV systems.

Open-Circuit Voltage (Voc)

Definition: The maximum voltage generated by a PV module or array when exposed to sunlight with no load connected.

Importance: All major PV system components (modules, wiring, inverters, charge controllers, etc.) are rated to handle a maximum voltage. Maximum system voltage must be calculated in the design process to ensure all

Model	Rated Power at STC (W)	Rated Power Tolerance (%)	Rated Power Per Sq. Ft. (W)	Module Efficiency (%)	Module Dimensions Length (In.)	Module Dimensions Width (In.)	Module Dimensions Depth (In.)	Weight (Lbs.)	Series Fuse Rating (A)	Connector Type
Trina Solar www.trinasolar.com										
165-DC01	165	+/-3	12.0	12.9	62.2	31.9	1.6	34.4	7	MC
170-DC01	170		12.3	13.3						
175-DC01	175		12.7	13.7						
180-DC01	180		13.1	14.1						
Uni-Solar www.uni-solar.com										
PVL-68	68	+/-5	5.6	6.1	112.1	15.5	0.6	8.7	8	MC
PVL-124	124		5.8	6.3	197.1			7.0		
PVL-136	136				216.0			7.7		
XC3 International www.xc3i.com										
XC1300 - 130	130	+/-5	12.5	13.4	57.8	26.0	1.5	26.0	10	J-box
XC2300 - 220	220	+/-3	12.7	13.7	64.0	39.0	1.5	53.6	10	MC
Yingli Solar www.yinglisolar.com										
YL175Wp	175	+/-3	12.3	13.2	52.6	39.0	2.0	34.6	N/A	J-box

components are designed to handle the highest voltage that may be present. Under certain low-light conditions (dawn/dusk), it's possible for a PV array to operate close to open-circuit voltage. PV voltage will increase with decreasing air temperature, so Voc is used in conjunction with historic low temperature data to calculate the absolute highest maximum system voltage. Maximum system voltage must be shown on the PV array disconnect label.

Short-Circuit Current (Isc)

Definition: The amperage generated by a PV module or array when exposed to sunlight and with the output terminals shorted.

Importance: The PV circuit's wire size and overcurrent protection (fuses and circuit breakers) calculations per *NEC* Article 690.8 are based on module/array short-circuit current. The PV system disconnect(s) must list array short-circuit current (per *NEC* 690.53).

PV technology and manufacturing techniques continue to make gains in efficiency.

Courtesy www.recgroup.com

Maximum Power Temperature Coefficient (% per degree C)

Definition: The change in module output power in percent of change per degree Celsius for temperatures other than 25°C (STC temperature rating).

Importance: This specification allows us to calculate how much module power will be lost or gained due to temperature shifts. In hot climates, cell temperatures can reach an excess of 70°C (158°F). Consider a module maximum power rating of 200 W at STC, with a temperature coefficient of -0.5% per degree C. At 70°C, the actual output of this module would be approximately 155 W. Modules with lower power temperature coefficients will fare better in higher-temperature conditions. Notice the relatively low values listed for thin-film modules. This specification reflects their usually-better high-temperature performance.

Open-Circuit Voltage Temperature Coefficient (mV per degree C)

Definition: The change in module open-circuit voltage in millivolts per degree Celsius at temperatures other than 25°C (STC temperature rating). Expressed as millivolts per degree Celsius in this table, but can be shown as percentage per degree Celsius, volts per degree Celsius, or volts per degree Kelvin.

Importance: If given, this specification is most commonly used in conjunction with open-circuit voltage to calculate maximum system voltage (per *NEC* Article 690.7) for system design and labeling purposes. For example, consider a series string of ten 43.6 V (Voc) modules installed at a site with a record low of -10°C. Given a Voc temperature coefficient of -160mV per degree Celsius, the rise in voltage per module will be 5,600 mV [-160 mV per degree Celsius x (-10°C – 25°C)], making for an overall maximum system voltage of 492 V [10 x (5.6 V + 43.6 V)]—under the 600 VDC limit for PV system equipment.

Nominal Operating Cell Temperature

Definition: NOCT is the temperature of each module, given an irradiance of 800 W/m^2 and an ambient air temperature of 20°C.

Warranty Materials (Yrs.)	Warranty Power (Yrs.) 90%/80%	Cell Type	Cells In Series	Max. Power Voltage (Vmp)	Max. Power Current (Imp)	Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coeff. (%/°C)	Open-Circuit Voltage Temp. Coeff. (mV/°C)	Nominal Operating Cell Temp. (°C)
5	10/25	Mono	72	35.60	4.65	43.2	5.20	-0.45	-151	47.0
				35.80	4.76	43.6	5.25		-153	
				36.20	4.85	43.9	5.30		-154	
				36.80	4.90	44.2	5.35		-155	
none	20	a-Si	11	16.50	4.10	23.1	5.10	-0.21	-88	46.0
			20	30.00		42.0			-160	
			22	33.00		46.2			-176	
5	25	Multi	36	17.76	7.38	22.3	7.79	-0.51	-78	50.6
			60	30.20	7.32	36.9	7.85		-129	
2	10/25	Multi	48	23.50	7.50	29.5	8.00	-0.45	-109	46.0

Importance: This specification can be used with the maximum power temperature coefficient to get a better real-world estimate of power loss due to temperature. The difference in cell temperature and ambient temperature is dependent on sunlight's intensity (W/m^2). Less-than-ideal sky conditions are common in many areas, so a standard of 800 W/m^2 is the basis for this specification, rather than 1,000 W/m^2, which is considered full sun. The construction and coloring of each module is slightly different, so the actual cell temperature under these conditions will vary per module.

For example, if a particular module has an NOCT of 40°C and a maximum power temperature coefficient of -0.5% per degree Celsius, power losses due to temperature can be estimated at about 7.5% [0.5% x (40°C – 25°C)].

Access

Justine Sanchez (justine.sanchez@homepower.com) is a NABCEP-certified PV installer, *Home Power* Technical Editor, and Solar Energy International instructor.

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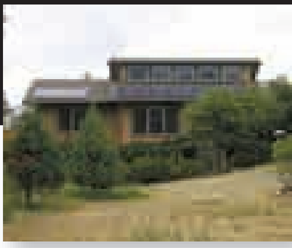
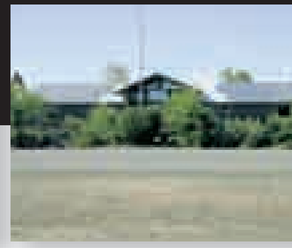
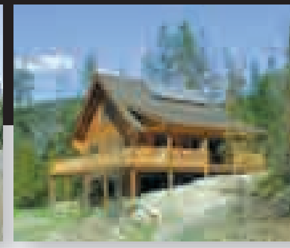
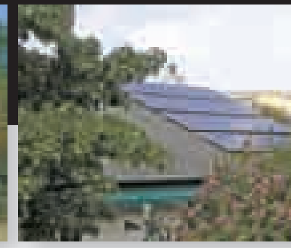
A well designed renewable energy system is much more than a pile of hardware.



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Battery Monitoring

What's in *Your* Bank?

by Khanti Munro

Nearly all residential-scale renewable energy systems require some sort of energy storage. In batteryless utility-interactive systems, the grid "stores" any unused energy as credits applied to future electricity use. But those of us living off-grid or with utility backup systems rely on something else for storage—batteries, those mysterious chemical-storage boxes.

Battery-based systems require more user involvement for optimal performance. If ignored, batteries can easily become the weak link in the system—and an expensive component to replace. But how do we know when batteries need our attention? We cannot tell how much energy is left in a battery simply by looking at it—a charged battery looks the same as a discharged battery. But special metering devices help us track what's happening inside our batteries so we can keep them performing at their peak and maximize their longevity.

Monitoring with Meters

Energy is constantly being put into or extracted from batteries, and the dynamic chemical composition inside reflects a varying state of charge (SOC). Voltmeters and hydrometers (which measure electrolyte specific gravity, reflecting the amount of acid in the water) can give indications of how fully charged the battery is. But measuring battery SOC with either of these devices requires accessing the battery terminals or testing the battery acid. This is like going to your bank's vault to count your money every time you want to check your balance. Thankfully, there's a device that monitors energy in and out, negating the need to directly access the batteries: the battery monitor, your batteries' personal bank teller.

Metering is typically dispersed throughout an RE system, like digital displays on charge controllers and inverters. But a battery monitor is in its own class as a system tool. It provides instantaneous values such as battery voltage and current, and also keeps a running tally of net energy into and out of the batteries. Like a bank teller recording your deposits (PV production) and withdrawals (household consumption), your battery monitor can provide you with a relatively accurate account balance (SOC).

Armed with this data, you'll know when energy needs to be conserved. And the monitor information can accomplish multiple tasks—help educate others about the system, analyze energy consumption to help improve household efficiency, troubleshoot the system if needed, keep a record of cumulative energy production over time, and even log some data about the battery bank's operating characteristics.

Battery capacity is measured in amp-hours (Ah), and a battery monitor's main responsibility is to measure the current in amps through a shunt (see "Shunt" sidebar) over time, and then compute the SOC and other data that is needed. A single Ah is the equivalent of 1 amp of current flowing for one hour.

VOLTMETER LIMITATIONS

Although incredibly useful, a multimeter's voltage display only provides a snapshot of what's happening with your batteries. While voltage does correspond to state of charge, it's a moving target. The ebb and flow of current into a battery affects battery voltage greatly. So unless a battery has been "at rest" without any charge or discharge for one to two hours (a rare occurrence, typically only accomplished by intentionally shutting off all power sources and loads), voltage will not accurately reflect SOC. A battery monitor, however, literally counts energy (amp-hours) in and out, providing a more reliable SOC estimate.

Battery Voltage vs. State of Charge

Voltage	State of Charge
12.7	100%
12.5	75%
12.3	50%
12.0	25%
11.7	0%

It could be 0.5 A flowing for two hours or 2 A for a half hour, etc. A battery bank is purchased based on a predictable need for a certain amount of Ah needed over a certain period of time; a battery monitor constantly compares the Ah in and out in a ratio to the battery's Ah capacity that was programmed into it. Subtracting the net Ah used from the battery's capacity gives the Ah remaining, which is normally expressed as a percentage of full.

Let's say you have an 800 Ah battery bank. If the battery monitor counts 300 Ah out (-300 Ah), and then 100 Ah back in (+100 Ah), the monitor will calculate a 75% state of charge:

[800 – 300 + 100] ÷ 800 = 0.75

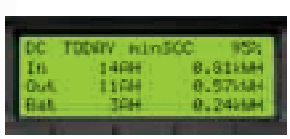
From left to right: Xantrex's LinkPro amp-hour meter and Bogart Engineering's PentaMetric battery monitor.

Courtesy www.xantrex.com, www.bogartengineering.com

Using the Meter Info

In addition to monitoring the SOC, you can use your battery monitor to verify the power usage of appliances and experiment with how different loads affect battery voltage. And you can watch how the incoming amps rise and fall with the changing weather and throughout the day—a battery monitor is more than just useful, it's actually interesting! Get to know your monitor—understanding what the monitor is showing you is as important as having the meter itself.

A battery monitor is only as accurate as the data programmed into it—garbage in equals garbage out. Programming is critical (battery capacity, battery pack voltage, etc.), as is the skill level of the installer who put it in. The correct shunts and data cabling are essential to successful operation. And always remember that the meter only gives you information, which is subject to your ability to interpret. What you do with that data is up to you—the meter will not water your batteries for you, clean the dust off their terminals, or prevent you from overdischarging the batteries. It should not be relied upon to manage your energy system—that is your job.



OutBack's FLEXnet (left) and a screen shot (right), showing battery bank daily input and output, as well as state of charge.

Courtesy www.outbackpower.com

WHAT'S A SHUNT?

A shunt is a precision resistor that allows the safe measurement of potentially high electric current. Placed in series (inline) with a current-carrying conductor, a shunt's low resistance creates very little voltage drop compared to other items in the circuit, so it consumes almost no energy. Measuring the voltage across the shunt gives the amount of voltage drop across that precise resistance. Those amounts are plugged into the Ohm's law equation to give an accurate computation of current flow in amperes through the circuit containing the shunt.

Shunts are rated by their maximum ampacity and the corresponding voltage drop in millivolts across them. A 500 A / 50 mV shunt will have a 50-millivolt voltage drop when 500 amps are flowing through it. The most common battery monitor shunts are 500 A / 50 mV and 100 A / 100 mV. Typically they are installed within the DC disconnect enclosure in series with the negative conductor, between the batteries and the inverter. But shunts can be placed anywhere that current needs to be monitored. Some newer monitors have multiple inputs for multiple shunts, so they can monitor a variety of inputs and outputs.

Ohm's law, **voltage (E) = current (I) x resistance (R)**, and its sibling equations (**I = E ÷ R** and **R = E ÷ I**) explain that if a 50 mV (0.050 V) voltage drop occurs at a current flow of 500 A, the resistance across the shunt equals 0.0001 ohms:

R = 0.05 V ÷ 500 A = 0.0001 ohms

The resistance of this shunt remains constant (0.0001 ohms), so the monitor can at any time compute the circuit amperage by plugging into its internal calculations the voltage drop across its shunt. For example, how much current is flowing if the monitor measures a 10 mV drop across the above shunt?

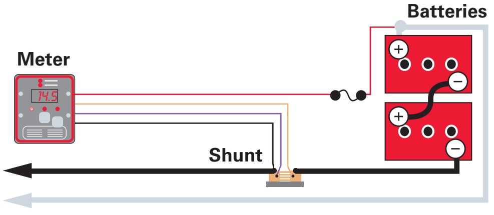
I = 0.01 V ÷ 0.0001 ohms = 100 A

System Integration

Battery monitors should be placed in a location that will both encourage attention and allow for easy access and operation. Mounting monitors in a visible and convenient location, such as in the kitchen or living room, makes them easier to use—they will sometimes become the center of attention with guests. Most monitors can be mounted in their own junction box or flush-mounted into the wall for an unobtrusive presence.

Battery monitors get their signal from the shunt through small-gauge, twisted-pair conductors (typically 16- to 22-gauge wire). While high current flows directly through the shunt, these monitor wires only measure the very small voltage drop *across* the shunt. By using twisted-pair cable, electrical "noise" and voltage induction that can affect monitor readings are lessened. Another twisted pair connects to the shunt to measure battery voltage and to power the monitor. Although the shunt is mounted in series with the negative conductor (between the batteries and the inverter) and usually within the DC disconnect enclosure, the monitor itself can be mounted hundreds of feet away in a more accessible location. The distance depends upon the wire size and the degree of accuracy required—the longer the signal wire, the greater the chance of induced voltage, which affects readings.

A Typical Battery Meter Installation



Note: Shunt is normally mounted within the DC disconnect enclosure (not shown). Exact wiring configuration is system specific and will depend on which battery monitor is being used.

ADVANCED MONITORING

Advanced functions and features can be found in many modern battery monitors, including:

- Time Remaining—Provides a rough estimate of how long the batteries could sustain a given load based on time-averaged increments (i.e., 4, 16, or 32 min.).
- Cumulative Amp-Hours—A cumulative count of Ah in or out of the batteries. Useful in estimating battery age or total charging-source production.
- Peukert Exponent—Factors in the discharge rate's effect on battery capacity.
- Charge Efficiency Factor—Accounts for charging efficiency losses.
- Multiple DC Inputs—To monitor more than one battery bank, charging source, or load simultaneously.
- Data Logging—Uses a communication port to export data to a computer, a data logging device, or the Internet.
- Remote Display—Allows a separate display to be conveniently mounted away from the monitor.
- Usage Readings in kWh—Make it easier to directly relate the amount of remaining battery capacity to the load ratings of household appliances.
- Relay Control—Activates a relay at a preset voltage point to start a generator, manage a load, etc.
- Alarms—Signal low battery, loss of meter power, etc.
- Battery Temperature—A sensor can be placed on the battery and wired into the monitor to report battery temperature.

Once the meter is mounted, a few basic user inputs must be manually programmed into the meter. First, program the Ah capacity of the battery bank into the monitor. Without this, the monitor cannot calculate the battery SOC. Be sure to specify the capacity at the battery's most relevant rate. Taking into account Peukert's Law, battery manufacturers list different Ah capacities for the same battery because a battery's capacity is lessened the faster it is discharged. A battery's capacity at a 20-hour discharge rate will be greater than at a 5-hour rate. For most renewable energy systems, the 20-hour rate best reflects how the battery will be operated.

The final manual programming tells the monitor when to consider the batteries fully charged. When the monitor detects that the high-voltage set point and the low-current threshold have been met, it assumes that the batteries have been fully charged and are now in float mode (where a low-current charge keeps the battery full). This automatically resets the "amp-hours from full" display, with the monitor reading "100%" or "Full," and sets the "days since fully charged" number to zero.

With a few minor programming details—such as selecting the desired battery reminders/alerts—and a thorough reading of the manual, your monitor will be up and running. Oh look, the bank's at 14.8 volts, I've got 18 amps coming in from the array, and it's been seven "days since laundry." Gotta go!

Access

Khanti Munro (khanti@solarenergy.org) instructs, coordinates, and develops curricula for the PV online program at Solar Energy International. He is an ISP Certified Instructor for Photovoltaic Courses and has been designing, installing, and educating about solar-electric systems since 2002.

Battery Monitor Manufacturers:

Bogart Engineering • www.bogartengineering.com • TriMetric & PentaMetric monitors

OutBack Power Systems • www.outbackpower.com • FLEXnet DC battery monitor

Xantrex • www.xantrex.com • TM500A, Link 10, Link 20, LinkLite & LinkPro battery monitors

new light FOR LEARNING

by Cecilia Diaz-Beneke & Ralf Seip

Courtesy Lourdes Seip

Courtesy Cecilia Diaz-Beneke

Left: Ralf and Cecilia assemble and test the system before its installation. Above: The array gets a permanent home atop the community building.

A small PV system brings light to the rural community of Setal, Guatemala.

In the 1990s, while working as a corporate security consultant, my father, Guillermo Diaz Salazar, decided to get back to his agricultural roots and restore degraded land in Alta Verapaz, an area in north-central Guatemala. He convinced a group of investors to transform 200 acres of eroded bush space into a pine tree farm that would provide jobs for local people and produce sustainably forested timber.

As part of the plan, the seven Mayan families who had lived on the land for generations were employed at the tree farm and given ownership of a 5-acre parcel to farm and live on. Collectively, the land and their huts—including one for my father—form the village of Setal. For his role, my father visits the community once every two months to manage the tree farm and help the people with their ongoing efforts to develop community infrastructure.

Building Community

Developing eroded rainforest into a tree farm has been a slow process, but in 15 years, the village has come a long way. Not only have the workers successfully cultivated the land and planted hundreds of trees, but the community pooled its resources to build a schoolhouse for the growing number of children in the area. Though rudimentary in form, the new school—a one-room hut with a tin roof and stick walls—was a tremendous step for the community.

With 70% illiteracy in rural areas, education offers the best hope for Guatemala to develop politically, socially, and economically. At the root of the problem is the language barrier that isolates many rural communities from the rest of the country and the world. Although Spanish is Guatemala's official language and is widely used for trading goods, it is not universally spoken outside of major cities. More than two dozen languages are spoken throughout the country—the Mayan dialect of Keqchi, for example, is the traditional language in Setal. Until a few years ago, only one of the men in the community spoke Spanish. With a curriculum taught in Spanish, the Setal school aims to increase fluency in the area.

The school opened in January 2006 with a program tailored for first- through sixth-grade students. But before long, it became clear that the adults in the village were also interested in learning to read and write in Spanish. Since they worked in the fields during the day, their classes needed to happen at night. That posed a problem because there was no electricity at the schoolhouse, and lanterns and candles could not effectively light the classroom.

Courtesy Cecilia Diaz-Beneke

During the day, eager young students gather to study. At night, a solar-electric system provides lighting for evening classes for adults.

A temporary solution came in the form of an old and battered gasoline generator that powered a few lights, allowing adults to attend night classes where they learned how to write their names for the first time. Unfortunately, the cost of purchasing and transporting gasoline to Setal was prohibitive, and the generator proved unreliable, breaking down two times in only a few months.

Assembling the PV array. For most, this installation was their first experience with electrical circuits.

Courtesy Cecilia Diaz-Beneke

Lighting the Way

I was born and raised in El Salvador, but my father and much of my family now live in Guatemala. Though I have lived in North America for 19 years and raise my family in Ohio, I still feel a strong connection to the region. After learning about the school from my father, my husband and I decided to get involved, and made plans to take our two young daughters to the village on our next trip to Guatemala.

Our girls spent months collecting books and supplies for the school, while my father and I raised funds to help with other community projects, including the village's first bathrooms with gravity-fed plumbing. We scheduled our visit for the end of the school's first year, so we could congratulate the students on their achievements. The girls were amazed to see how such small contributions—colored pencils, notebooks, pens, and the like—brought so much joy to the people of Setal. While we'd done more than most, it wasn't enough for me. I was determined to help further, and I knew exactly who to turn to.

My childhood friend Ralf Seip is a longtime solar energy enthusiast. In the 1980s, Ralf bought his first PV modules to power a cassette player so we could listen to music at the beach. Now, a utility-intertied PV system at his home offsets almost half of his family's annual electricity use. (See "Experimenting with Solar Hot Air Collectors" in *HP72* and "Growing with the Sun," in *HP107*.)

Designing with Purpose

As soon as I told Ralf about the school, he suggested an alternative to Setal's gasoline generator: a battery-based solar-electric system that would provide clean, reliable electricity. The idea quickly took shape, and we got to work immediately, soliciting funding and donations for the project.

Since I had no experience in PV design or installation, I followed Ralf's lead. He started by estimating the schoolhouse's electrical loads, figuring that the 16- by 20-foot classroom would be well-illuminated by four compact fluorescent lights (CFLs). A fifth light outside the schoolhouse door would provide added security and safety. The four interior lights would be used as necessary (approximately 4 hours nightly) while the outside light would remain lit throughout the night (approximately 12 hours).

Courtesy Alejandro Novales-Woodside

The PV array on its custom rack is carried to the schoolhouse along muddy footpaths from the road's end.

To maximize energy availability and minimize system costs, Ralf chose to bypass the use of an inverter and use 12-volt DC compact fluorescent lights. He determined that the five 7-watt CFLs would consume 196 watt-hours of energy each day and would require about 16 amp-hours from a 12 VDC battery bank. To prolong battery life and to have some remaining capacity to supply lighting during cloudy periods, Ralf did not want the batteries discharged by more than 15%, and sized the bank accordingly. A 102 Ah, 12 VDC battery bank met this criteria. A 90 W, 12 VDC PV array is capable of replenishing this capacity on a typical day with 5 peak sun-hours, as Ralf conservatively estimated based on 80% module efficiency, 95% charge controller efficiency, and 80% battery efficiency.

Preparing for the Unexpected

In the far corners of the Guatemalan jungle, there are no local hardware stores or overnight delivery services for last-minute needs—preparation is key. To work out some of the kinks in advance, Ralf preassembled and tested the system at his home in Indianapolis. Since he would be unable to make the trip to Guatemala, he walked me through the design and installation to ensure that I could reassemble the system. Once in Setal, I would need to lead my father and the community members through the installation process. Preassembling the system ensured that we had everything we needed and everything was in working order. Knowing that this would be my first PV installation, Ralf cut the wires to size so I could focus on the mechanical installation when in Setal.

Early in the design phase, Ralf and I decided that we would save on shipping costs and transport the components by packing them in my luggage. Carrying the components also ensured that everything arrived in one piece and on time to Guatemala City, where I met my father. Miraculously, everything we needed—the charge controller mounted on a wood support; seven 12.6 W, 11- by 17-inch PV modules; 12 VDC CFLs; wiring; and assorted small hardware—fit in two suitcases.

Transport Travails

Upon my arrival in Guatemala City, my father and I had one day to collect the remaining hardware before departing for the village. In addition to the supplies for the mounting frame, we locally acquired two Deka sealed lead-acid batteries. We loaded up the supplies and hit the road.

Transporting the system components and supplies to Setal wasn't nearly as smooth or comfortable as the first leg of my trip. Potholed dirt roads made the nine-hour drive through the countryside and jungle feel like an eternity. But the incessant bumps were nothing compared to the two-hour trek to the village. After driving all day, we arrived at the end

Setal System Costs

Item	Cost
7 DMSolar PV modules, 12.6 W	$531
ProStar 30 charge controller	223
2 Deka 8G22NF batteries, 12 V, 51 Ah	220
6 L-CF 7 CFL bulbs, 12 V, 7 W (incl. 1 spare)	108
Shipping	80
Fuses, wire, miscellaneous	75
Total	**$1,237**

of the dirt road, where we left the car and found men from the village waiting for us. They came to help us carry the supplies and system components for the remaining two-hour muddy trek to the village. Since hauling heavy loads on their backs is a way of life for the locals, the supplies and equipment posed no real challenge to them. They practically ran up the hills while we struggled with our small packs.

Putting It Together

With a small crew from Setal, it took us three days to execute Ralf's plans for installing the PV system. The schoolhouse roof offered a perfect place to mount the array, but we had to build a custom rack to face the modules south on the sloping roof. This turned out to be the most difficult part of the project, as some of the materials and tools were not on site as expected. We ended up removing wallboards from my father's hut to build the module rack's base.

Using rough hardwood boards left from the school's bathroom building, the Setal men built a battery box that could be locked for safety and security. The charge controller was installed next to the battery box in the schoolhouse. Running the pre-cut wires and attaching the lights to the crossbars on the ceiling of the schoolhouse rounded out the installation. Having the village men help with the installation and module wiring gave me a chance to teach them about basic electricity, safety, and system maintenance. Having no experience with electricity, the whole crew looked at this as a new beginning and a great learning tool.

Community Coordination

Simple and reliable components that could be easily maintained over time were selected for this system. We chose a charge controller with a low-voltage disconnect and wired all of the loads through it. This means that energy will stop flowing to the loads when the controller detects a low voltage on the batteries—11.4 V in the case of the

The batteries, safely housed in a lockable battery box that was built on site.

Courtesy Guillermo Diaz Salazar

Morningstar PS-30. Power will be restored only after the controller detects a battery voltage that exceeds 12.6 V. This feature helps extend the life of the batteries and prevents abuse from overdischarging. We also simplified system maintenance by using sealed lead-acid batteries that do not require watering.

My father and I trained community members to read and interpret battery health and system status using the Morningstar controller's display. This enables them to manage loads (i.e., turn off lights or use fewer lights) and activities based on the available solar resource and battery state of charge.

With grid electricity in the region still a decade or two away, PV arrays are valuable and sought-after commodities. After a solar-electric system was stolen from a nearby clinic, the community decided to take extra measures to protect its system. Men from the participating villages now take turns spending the night at the schoolhouse to watch over the system. This, along with the outside light, a locked battery box, and a securely attached PV array, should deter bandits from burglarizing the system.

The community in front of the new schoolhouse, looking forward to the benefits of solar-electric lighting.

Courtesy Cecilia Diaz-Beneke

Illumination & Education

After one final check of the polarity, voltages, and charging current, the moment came to switch on the system. It was standing room only in the schoolhouse, when Cristina—a shy 15-year-old—flipped the switch and filled the schoolroom with light.

The system has been operational since that ceremonious night in December 2007, and according to my father's reports, it is serving the community well. The school now has 26 day students: 14 boys and 12 girls, ranging from 4 to 16 years old. Twenty-two adults—12 men and 10 women—gather three times per week for night classes. Interest has been so great that adults and children are coming from as far as three miles away to attend the Setal school. And, on weekend evenings, the community takes full advantage of the lights by using the schoolhouse as a prayer hall and a gathering place for celebrations and meetings.

Looking to the Future

Ralf intentionally oversized the charge controller, which can handle 30 A of solar charging current, to allow for future system expansion by adding more PV modules, batteries, or both. Choosing 12 VDC as the system voltage gives great flexibility for module additions, since these are readily available to ship and can easily be paralleled to increase production. This allows us to accommodate future donations more easily, as modules can be bought online one at a time.

Ralf, my father, and I remain committed to helping the community of Setal become a regional hub for education, community activities, and basic health care, all while empowering the people with increased control over their future. We've had great donations from the RE community, including the controller from Morningstar, the CFLs from Backwoods Solar, and module shipping covered by DM Solar. The additional funds needed came from friends and family. Plans are already underway to expand the capacity of the system to support a TV/VCR system for educational programming. We are also looking for support to add two additional solar-electric systems to the community: one to power lights for six huts and another to support refrigeration and lights for a small health clinic set to open next year.

Access

Cecilia Diaz-Beneke (setalguatemalavillage@gmail.com) is a chemical engineer with a specialty in polymers. She is currently taking a break from her career to raise her daughters, Maia and Karina.

Ralf Seip (poi.poi@earthlink.net) is an engineer working in the medical device field. He is in the process of relocating his family, along with his home's solar-electric system, from Indianapolis to New York for job-related purposes.

System Components:

Backwoods Solar • www.backwoodssolar.com • 12 VDC CFLs

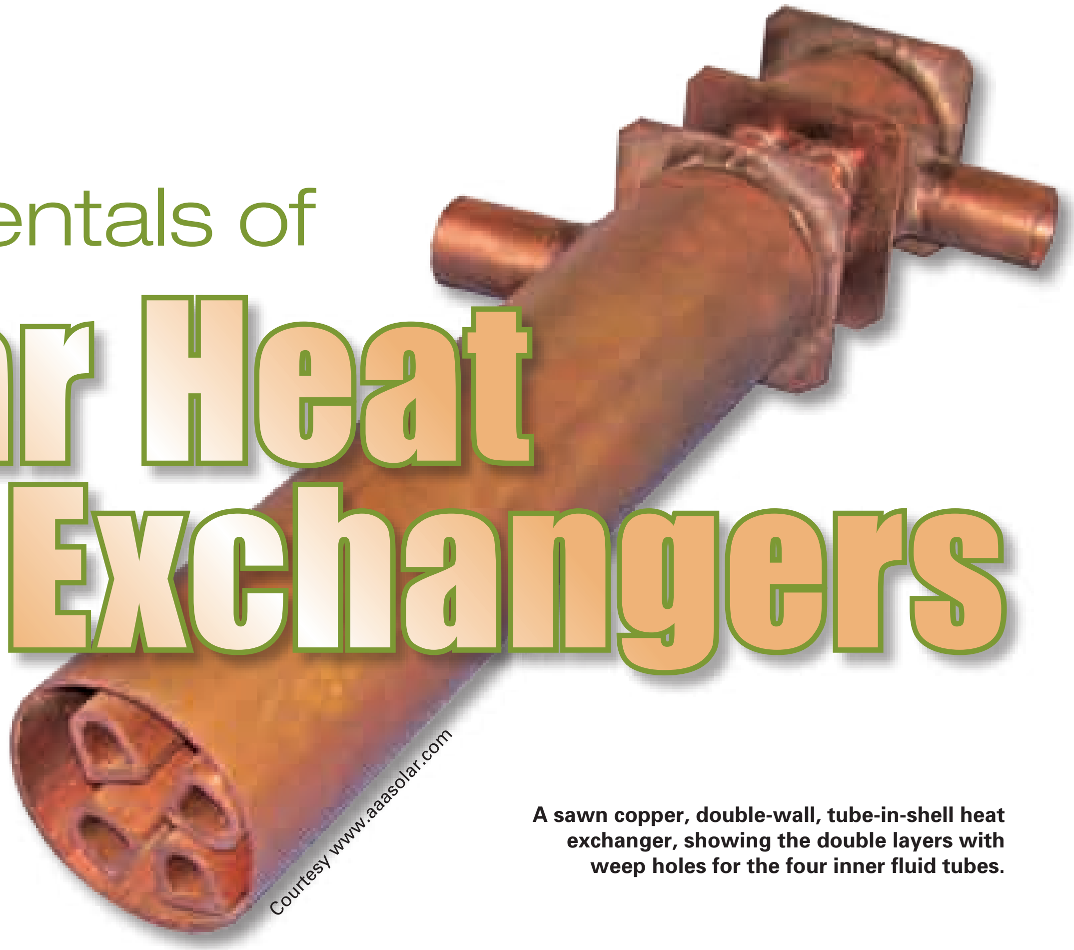
Dmsolar • www.dmsolar.com • PV modules

East Penn Manufacturing • www.eastpenn-deka.com • Batteries

Morningstar • www.morningstarcorp.com • Charge controller

Fundamentals of

Solar Heat Exchangers



Courtesy www.aaasolar.com

A sawn copper, double-wall, tube-in-shell heat exchanger, showing the double layers with weep holes for the four inner fluid tubes.

by Chuck Marken

You might not realize it, but heat exchangers are a part of everyday modern life. Every car has two or three of them; most homes have three or more. Wood heaters and baseboard radiators are heat exchangers. Refrigerators have a couple tucked away. And all drainback and antifreeze solar hot water systems—among the most common SHW types—need a heat exchanger for freeze protection.

Heat exchangers can be air to air (forced-air furnace), air to liquid (car radiator), or liquid to liquid (most SHW heat exchangers). This article covers liquid-to-liquid exchangers exclusively, although most of the rules for good heat exchange are applicable to all configurations.

Heat exchangers in SHW systems are used to transfer heat from one fluid (the heated collector fluid) to another (usually stored water), with heat flowing from the hotter fluid to the cooler fluid. By definition, no contact between the two fluids occurs within a heat exchanger. Instead, heat transfer is accomplished by conduction through the metal walls in the exchanger that separate the two fluids.

Exchanger Design Factors

Wall materials, exchange surface area, and construction all impact heat-exchanger performance. Here are the most important parameters.

Material conductivity. The thermal conductivity of the heat exchanger material is an important factor in system performance, but it is often overlooked. Make a heat exchanger out of glass and you'll learn the game—it will work, but you'll be disappointed by its poor efficiency. The more insulative the material, the worse it will perform as a conductor of heat. I've never seen a SHW heat exchanger worth a nickel that wasn't made out of metal.

A major water heater manufacturer once made a tank with an internal, coiled double-wall heat exchanger—copper tubing covered with a high-temperature PEX (high-density, cross-linked polyethylene)—but the product was discontinued after a couple of years. The bottom line: All metals have good-to-excellent thermal conductivity. Plastics and other thermal insulators typically have poor conductivity, making for less effective heat exchangers.

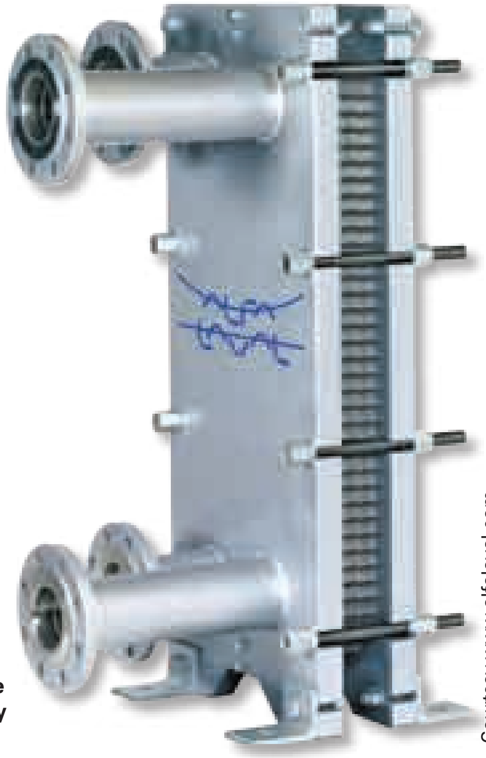
Surface area. An exchanger's heat-transfer surface area is very often the most important design parameter. It must be large enough to transfer the heat to where it's needed. Too small a heat exchanger will simply give unsatisfactory performance.

A high ratio of the exchanger surface area to the volume of liquid within the inner tubes makes for better heat transfer. A

good example can be demonstrated if you have a thermometer. Take a few ice cubes, crush them into small pieces, and place them in a glass. Take an equal number of cubes and place them in another glass of equal size without crushing them. Fill both glasses with an equal measure of water from the kitchen tap. Wait a couple of minutes and measure the temperature of both glasses of water. Although both have an equal volume of ice and the temperature of the ice and water are the same when the glasses are filled, the glass with the crushed ice will be colder. What's at work? The surface-area-to-volume ratio of the crushed ice is greater and serves to better exchange the heat.

While the surface-area-to-volume ratio is important, sacrificing total surface area for a higher surface-to-volume ratio can result in less heat exchange. For example, using a smaller-diameter tube increases surface-to-volume ratio but decreases the total surface area and can be detrimental. The surface area decreases less than the volume. This is true for all cylinders (tubes)—very large tubes have much less surface area compared to the volume of liquid in the tube—and results in less heat exchanged. Although the heat exchange is better with the smaller tube, the design needs to ensure the volume is large enough to not impede the flow.

Physical configuration. A solar heat exchanger is usually designed in one of three ways—with coiled tubing, plates, or tube in shell. Coiled heat exchangers are used inside of or wrapped around storage tanks. Plate heat exchangers are generally preferred when single-wall heat exchangers are acceptable. Tube-in-shell heat exchangers are the design used for most double-wall external heat exchangers.



Courtesy www.alfalaval.com

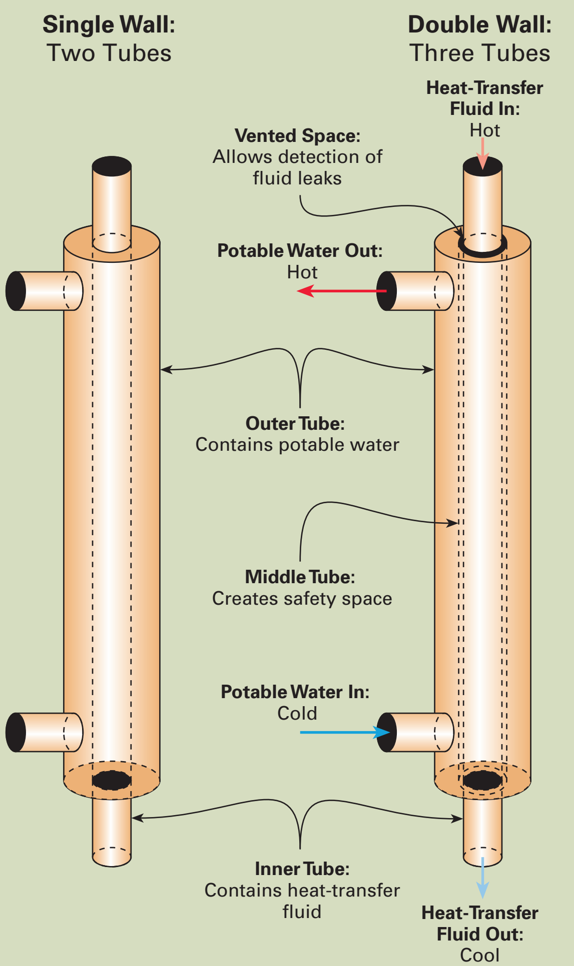
A large plate-style heat exchanger by Alfa Laval.

Regulations: Avoiding a Red Tag

The 2006 Uniform Solar Energy Code specifies that heat exchangers in SHW systems transferring heat to potable water must be double-walled—no exceptions—to prevent possible mixing from occurring in the event of a leak. I've always thought this rule was excessive when nontoxic propylene glycol is used and even debated a local inspector about it once (do so at your own peril).

His logic was this: Even if *I* always used nontoxic glycol as the system antifreeze, how could he or I ever prevent someone else from filling the system with toxic—potentially lethal—ethylene glycol in the future? Unless your local building department approves of single-wall heat exchangers in SHW systems or your favorite tag color is red, stick with the double-wall design.

Single Wall vs. Double Wall



Courtesy www.rheemsolar.com

The Rheem Solaraide HE is a storage tank with an integrated, wraparound heat-exchange coil.

Heat exchangers are either external to the tank or housed inside the tank (internal). I've read a couple of well-respected books that claim that external heat exchangers are more "efficient" than internal heat exchangers. The books don't give a reason why. Perhaps the reference is to the difference in external *plate* heat exchangers and internal *coil* exchangers. Since it is almost impossible to make an apples-to-apples comparison of the two designs, I still question this blanket claim.

Bonding. The design of a double-wall heat exchanger calls for the two walls to be thermally bonded together and also have a path to the atmosphere so leaks can be detected. A heat exchanger's effectiveness depends on this bond. In most cases, a simple, press-fit mechanical bond is not sufficient. The mechanical bond must be augmented with heat-transfer paste to ensure good conductivity between the two walls of the heat exchanger.

System Design Factors

Besides the exchanger's design and construction, how well it works within the system is critical. These factors all influence system efficiency.

Delta T (ΔT, temperature difference). The larger the temperature difference between the fluid in the heat exchanger and the water in the tank, the better the heat exchange will be. When the difference in temperature is only a few degrees (a low ΔT), less heat is transferred in the exchanger.

Flow rate. Generally, the higher the flow rate through the SHW system, the better the heat exchange. More flow means that more liquid volume is available for its heat to be exchanged. More powerful pumps and larger-diameter pipes help improve flow rate.

Fluid type. Water has the highest heat-content capacity (specific heat) of common fluids. Antifreeze (propylene glycol) solutions have about 70% of the heat-content capacity of water and this affects the heat-exchange efficiency in the system. However, fluid-type efficiency is less of a factor than the efficiency and surface area of the exchanger itself.

An inefficient heat exchanger will have a high ΔT between the two fluids. While this normally makes the heat exchange more efficient, the overall system efficiency suffers because the collectors operate at higher-than-necessary temperatures.

An external, tube-in-shell heat exchanger (far right) with other balance of system components, like circulator pumps (far left) and an expansion tank (center).

Courtesy www.aaasolar.com

The high ΔT can be caused by many factors. Low flow rates, small heat-exchange surface areas, and low surface-to-volume ratios, or a combination of these factors can all affect the heat-exchange efficiency and overall system efficiency.

System Designs

SHW heat exchangers can be internal, external, or wraparound. All of the systems can be configured as either single- or double-wall designs, except the wraparound, which by its nature is a double wall, since the tank is one wall and the wall of the tubing is the other.

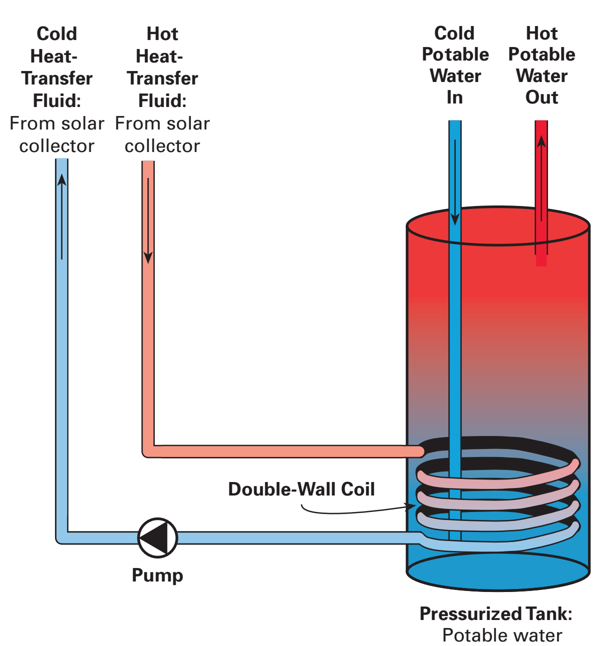
Internal Exchangers

Immersed exchanger in a pressurized tank. This efficient design puts the domestic hot water in contact with the outer wall of the heat exchanger. The efficiency of the double-wall design used in antifreeze/glycol systems depends a great deal on the bonding between the two walls.

These tank/exchanger designs are usually the most expensive. However, one design (the Solar Wand; see Access) lends itself to insertion into the tank, screwing into a 3/4-inch port at the top of the tank. This design is useful when you need to use an existing water heater as the solar storage tank.

Be aware that copper heat exchangers placed in glass-lined steel tanks are predisposed to causing premature tank failure—after the large mass of copper has devoured the tank's sacrificial anode rod, it then attacks through the imperfections in the tank lining to eventually corrode the tank itself.

Immersed, Bonded, Double-Wall Heat Exchanger



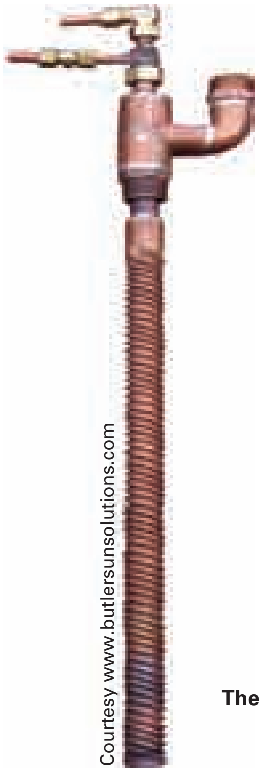
Area, Volume & Performance

A good example of heat-exchange effectiveness is shown by comparing the surface area and surface-area-to-volume ratio of the two heat exchangers pictured below. The large copper tube-in-tube exchanger was originally installed on a solar thermal system heating an indoor swimming pool. It has a total heat-exchange surface area of 65 square inches. The five 1/2-inch-diameter inner tubes total a volume of 36 fluid ounces, for a ratio of 1.8 to 1. The plate-type stainless-steel heat exchanger shown in front of the copper exchanger has a total exchange surface area of 720 square inches and total volume of only 15 fluid ounces, a 48:1 ratio—offering both a higher surface area and a higher surface-to-volume ratio.

The proof was in exchanging the exchangers. The tube-in-tube heat exchanger was unable to heat the pool successfully, while the plate exchanger allowed the system to perform as designed and heat the pool without any other modifications.

The original tube-in-tube heat exchanger and the more efficient plate-type heat exchanger.

Courtesy www.aaasolar.com



The Solar Wand from Butler Sun Solutions is an internal heat exchanger that fits into any standard water heater port.

Immersed exchanger in an unpressurized tank. Any material that will withstand 212°F is suitable for an unpressurized storage tank. Steel, stainless steel, concrete, fiberglass, polypropylene, and EPDM rubber have all been used successfully as unpressurized tanks.

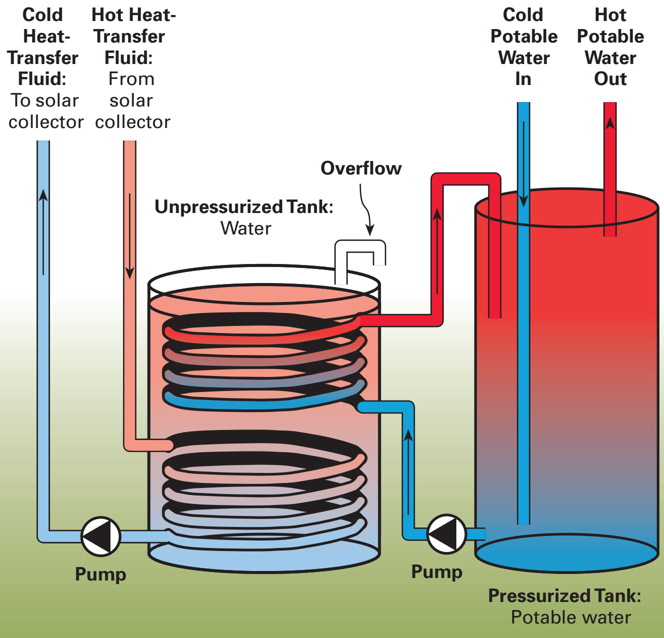
Most drainback systems use the potable water in the tank as the collector-loop fluid, but for antifreeze systems, a coil circulating the antifreeze solution can be inserted in the tank. Since the potable domestic water is circulating simultaneously through a similar immersed coil, the two walls of the coils effectively make a double-wall exchanger. The unpressurized tank system is a great choice for SHW systems performing more than one job. For instance, a domestic water heating and radiant floor system would each have a separate coiled heat exchanger.

External Exchangers

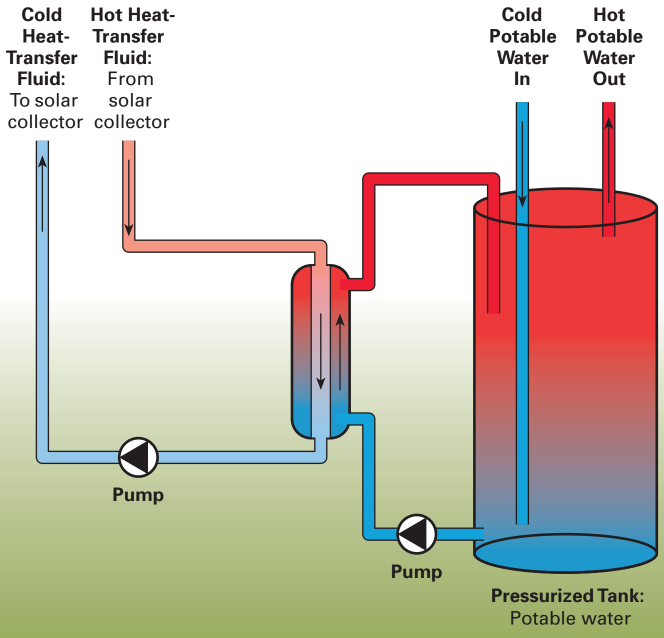
External heat exchanger. This design offers the flexibility of using any type of pressurized tank in the system. Slightly modified electric water heaters make excellent solar storage tanks when used with external heat exchangers. Typically, two pumps are required for external exchanger systems—one to circulate potable water from the tank to the exchanger and another to circulate the heat-exchange fluid from the collector to the exchanger—but some external exchangers can avoid one pump by thermosyphoning on the tank side. The shell or tube (waterway of the DHW) of a good thermosyphoning heat exchanger is fairly large to cut down on frictional head loss.

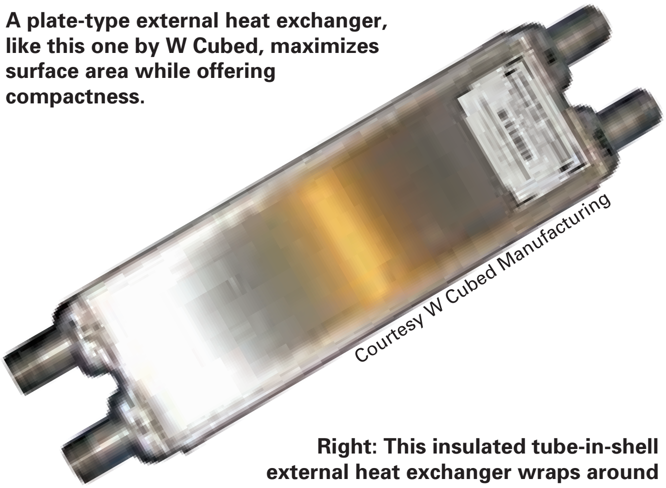
The external exchanger can be single or double wall depending on the collector-loop fluid or the fluid to be heated. (See *HP97* for an article on how to build a single-wall, tube-in-tube exchanger for a drainback system.) Stainless-steel plate heat exchangers are the most popular for heating radiant floors and other applications not heating potable water.

Immersed, Double-Wall, Double-Coil Heat Exchanger (Multiple Pass)



Exterior, Vented, Double-Wall Heat Exchanger




Courtesy W Cubed Manufacturing

A plate-type external heat exchanger, like this one by W Cubed, maximizes surface area while offering compactness.

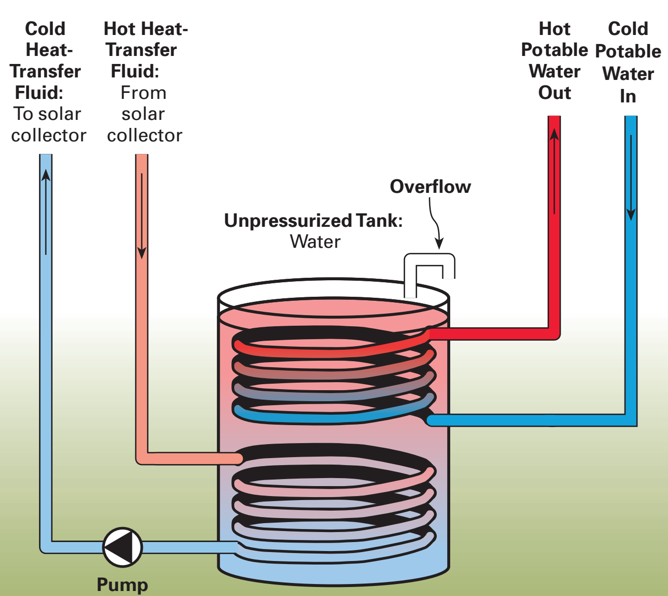
Courtesy www.aaasolar.com

Right: This insulated tube-in-shell external heat exchanger wraps around the expansion tank to save space.

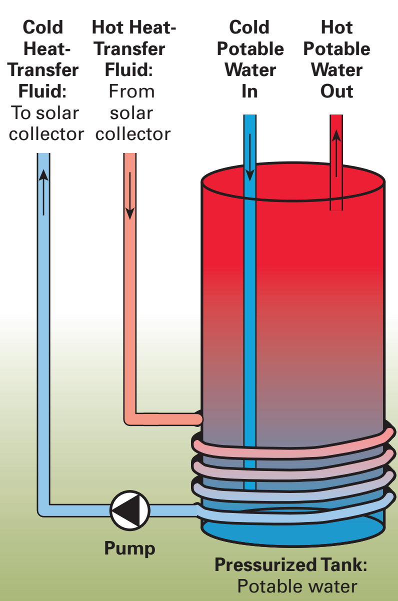
Instantaneous (a.k.a. single-pass) exchangers. These exchangers are designed for use with potable domestic water. The water is not circulated into storage but makes a single pass though the exchanger on its way to the point of use. For this exchanger to be effective beyond very modest use patterns, its surface area and surface-to-volume ratio need to be very high.

Single-pass heat exchangers have a reputation of disappointing their users. Typically, the only way you can have sustained hot water with a single-pass exchanger is to have hundreds of feet of exchanger tubing and enough of them in parallel to handle the needed flow.

Instantaneous Immersed, Double-Wall, Double-Coil Heat Exchanger



Wraparound, Double-Wall Heat Exchanger



Wraparound heat exchangers. This design is probably the most widely used in systems using Solar Rating & Certification Corporation-certified SHW collectors. (This certification is required for residential solar water heaters to be eligible for the federal tax credit). The system requires a single pump and is easy to adapt to drainback and antifreeze designs. While the tank is costly, it reduces labor costs because it is simpler to install. These tanks are equipped with a backup electric heating element in the top of the tank.

The design of a heat exchanger is very important in the efficiency of any freeze-protected solar water heating system. Less costly heat exchanger designs usually require more labor and materials for installation. The costlier designs are easier to install but offer less flexibility, and tank replacement will warrant a higher repair bill.

Access

Contributing editor **Chuck Marken** (chuck.marken@homepower.com) is a New Mexico-licensed plumber, electrician, and heating and air conditioning contractor. He has been installing and servicing solar thermal systems since 1979. Chuck is a part-time instructor for Solar Energy International.

Heat Exchanger Manufacturers:

AAA Solar Supply Inc. • www.aaasolar.com • External double-wall exchangers

Alfa Laval Inc. • www.alfalaval.com • Small plate exchangers & large double-wall exchangers

Butler Sun Solutions • www.butlersunsolutions.com • Double-wall exchanger

Doucette Industries Inc. • www.doucetteindustries.com • Double-wall & plate exchangers

W. Cubed Manufacturing & Engineering • Phone/Fax: 303-431-1180 • Flat-plate exchangers

Tank & Exchanger Combination Manufacturers:

Rheem Water Heaters • www.rheem.com • Wraparound double-wall exchangers

Vaughn Manufacturing Corp. • www.vaughncorp.com • Double-wall exchangers bonded in a pressure vessel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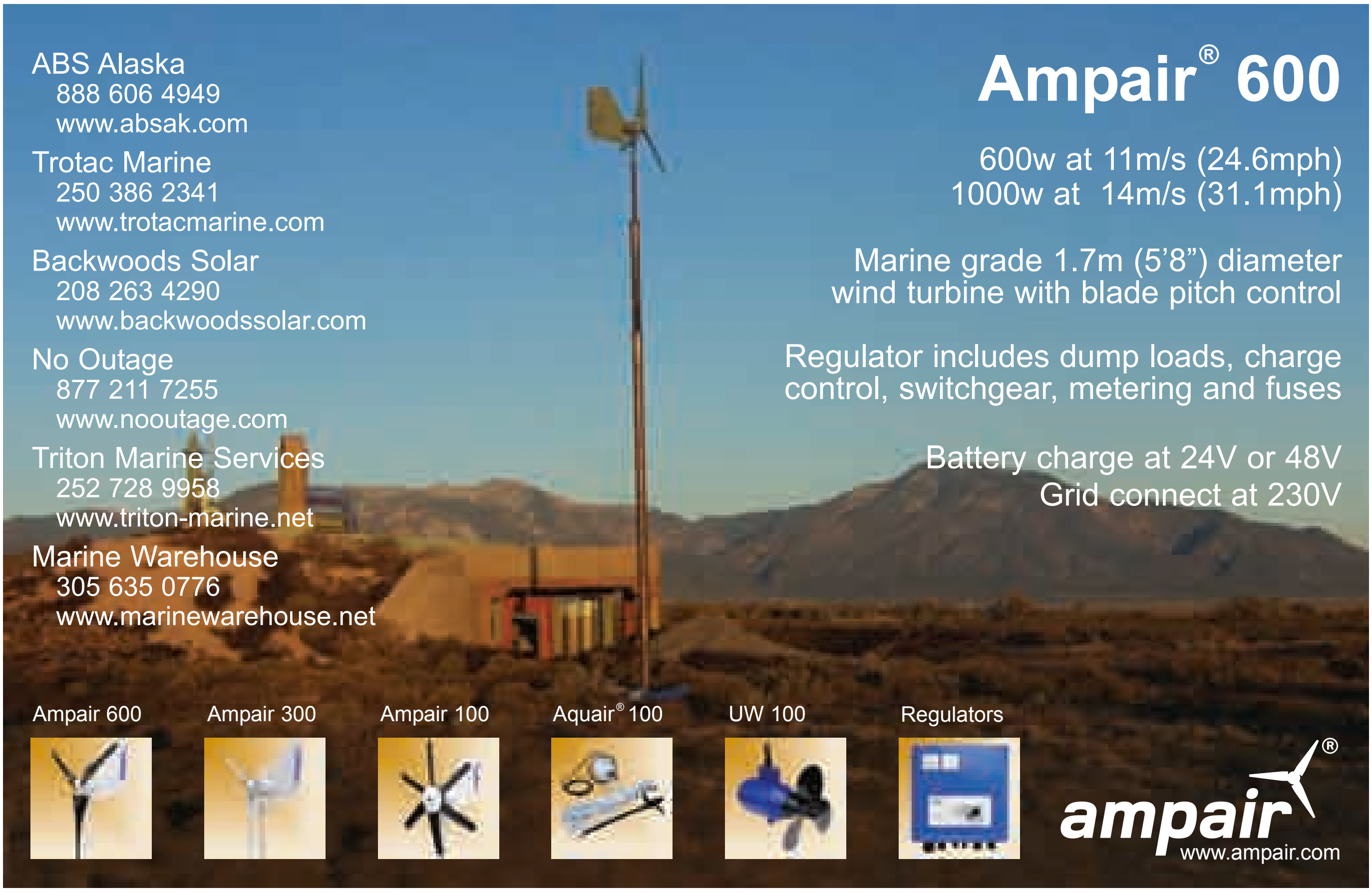
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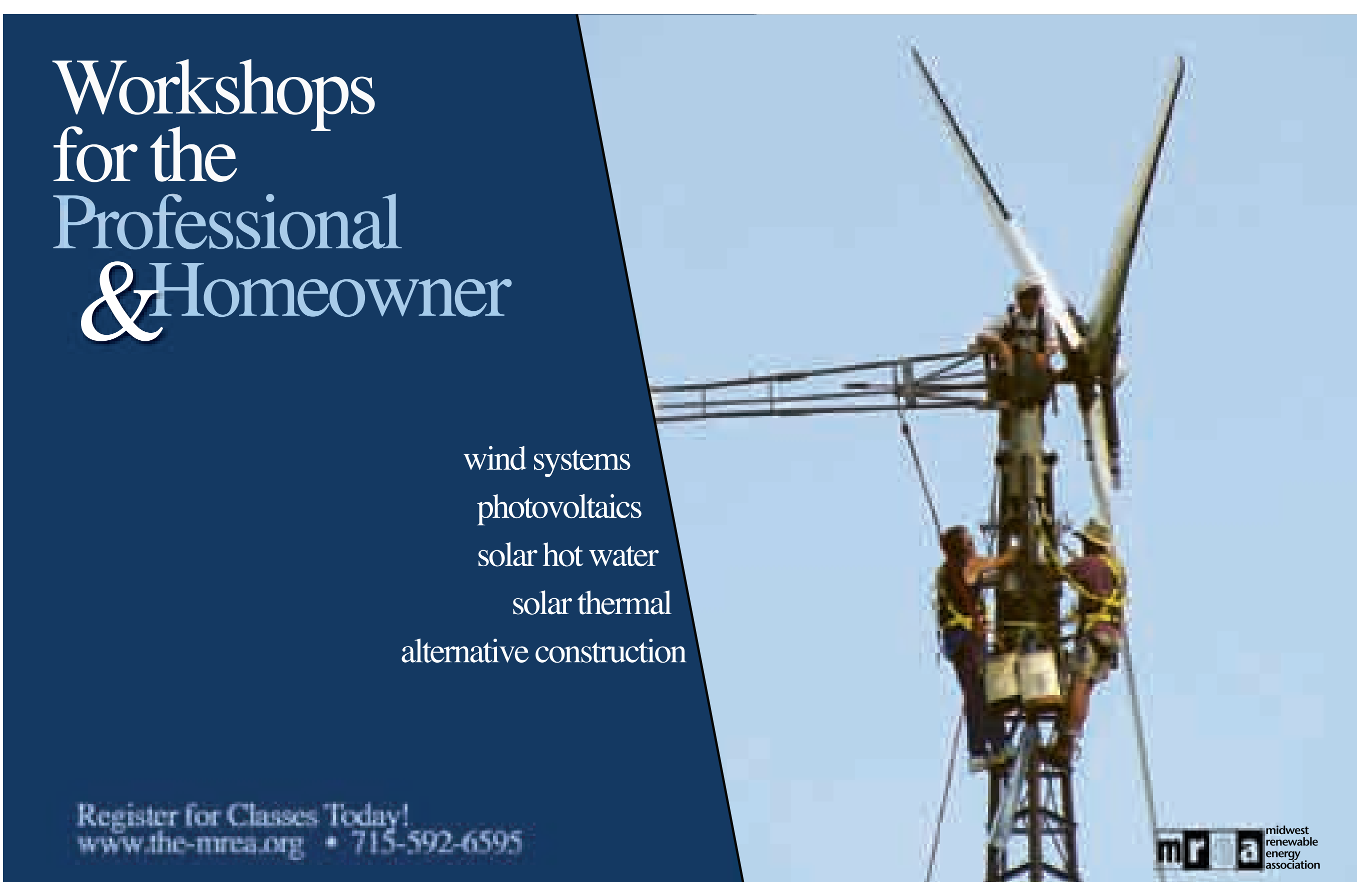
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Roof-Mounted

PV System Design Challenges

by John Wiles

Designing and installing a PV system requires a lot of knowledge and skill. This column examines some of the less common issues faced in mounting rooftop PV arrays. This information may also be useful for potential PV system owners in evaluating the feasibility of a roof-mounted array.

Mechanical Considerations

The typical rooftop PV array consists of individual modules attached to a mechanical mounting system. This framework is usually attached to the roof's structural members. Although not an electrical-code issue, some attention must be given to the array's attachment to the building structure.

Most roofs are being designed based on span tables dictated by building codes or with trusses designed by professional engineers to accommodate live and dead roof loads. Adding a PV array to this structure brings its own considerations. A PV array may add up to 10 pounds per square foot of dead weight to the roof structural members, concentrated through the rack mounting feet. Because the PV array is typically elevated above the roof plane, the roof may be subjected to both uplift and down-force wind loads—again concentrated through the mounting feet of the rack. When further weighted with layers of old roofing materials, the structural limit of the roof may be breached.

Array mounts attached to the structural elements of a roof (trusses or rafters) require penetrating the roofing surface material and must be weatherproofed for the life of the roof. Stainless steel hardware is usually used to connect the modules to the racks for the corrosion resistance that is a must in most climates.

Electrical Connections

The PV array consists of PV modules wired in series using exposed single-conductor cables with "finger-safe" connectors. The conductors are typically USE-2 as allowed by *NEC* Section 690.31. In the *2008 NEC* Section 690.35, a new PV wire type is also allowed. This conductor is a "super" USE-2 with a thicker jacket (conduit-fill tables cannot be used with this cable). The PV wire, which is marked "Sunlight Resistant," passes a 720-hour accelerated UV test, and has the flame and smoke retardants of RHW-2. It can be used under and within the PV array for the module interconnections and in raceways in other locations. This new cable will soon be appearing on all modules because it facilitates the use of ungrounded PV arrays (as required by *NEC* 690.35) and transformerless inverters, offering less weight, higher efficiency, and lower-cost installations.

Most modules do not have J-boxes with knockouts for conduit, but come with single conductor cables with male and female connectors.

The electrical connectors attached to the ends of the module cables are "finger-safe"—until they are opened under load. The DC arc may damage the insulation, and then the connectors pose a shock hazard. Section 690.33 of the *2008 NEC* stipulates new requirements for locking connectors that require a tool for opening. These locking connectors will also soon appear on most, if not all, PV modules—although they are only required when the PV array wiring is operating above 30 volts and is readily accessible.

Another *2008 NEC* requirement applies to readily accessible PV source and output circuit conductors and AC conductors operating at more than 30 volts. Section 690.31(A) requires that these conductors must be installed in raceways. But most PV modules do not have junction boxes with knockouts that would accept a raceway—they come with permanently attached, exposed, single-conductor cables and connectors with no provision for attaching a conduit or other raceway. Fortunately, most residential rooftop PV arrays are not readily accessible.

For ground-mounted arrays that are readily accessible, a few manufacturers can provide conduit-ready modules on special order. The other solution is to make the wiring not readily accessible by placing some sort of barrier behind the modules that prevents the wiring from being touched.

A stainless steel loop strap and mounting bolt for securing module conductor leads.

Oops: An indoor lug and wrong conductor type were used for grounding this standing-seam metal roof.

However, fences with locked gates may not be a solution, because ground-mounted PV arrays usually need to have the grass mowed around them—a task usually done by people not qualified to work on PV or other electrical systems.

Another wiring consideration is conductor length and module orientation. Typically, conductor leads attached to modules are 40 inches or longer to allow series connection when modules are mounted in a landscape orientation. When the modules are mounted in portrait orientation, the excess lengths of conductors must be securely fastened against the module racks to resist abrasive damage due to wind, sleet, and ice. Many installers use plastic cable ties, but unless they are of very high quality, they may not last the required 40 years or more when exposed to the heat and UV radiation from sunlight. Some system integrators use a stainless-steel pipe clamp (a.k.a. loop strap) with an EDPM insert.

Single-conductor exposed wiring (USE-2 or PV wire) is allowed only in the near vicinity of the PV array to interconnect the modules and to return the end of the string conductor to the origination point of the string wiring (which is generally routed behind the modules). At this point, the exposed wiring must transition to one of the more common wiring systems found in Chapter 3 of the *NEC*. Typically, this transition will take place in a pull box, conduit body, or junction box. From there, the wiring will be run in some form of conduit, such as EMT. The transition device keeps water, dirt, rodents, and other material out of the conduit. Also, a rain head or a cord grip might be used, connected directly to the conduit in situations where a single type of conductor will be used for the entire DC system.

If the array output conductors penetrate the surface of the building before reaching the first readily accessible DC PV disconnect, then they must be housed in a metal raceway inside the structure. Metal raceways include rigid metal conduits and flexible metal conduit (FMC), but do not include metallic cable assemblies like Type MC and Type AC.

Grounding

Section 690.47(D) in the *2008 NEC* requires that metal surfaces of the PV array be connected directly to earth via a separate grounding electrode. This requirement provides a greater degree of lightning protection for PV systems than other *NEC* requirements and is in addition to the normal equipment-grounding conductors that run with the circuit conductors connected to earth (grounded) at locations remote from the PV array. If the array is on the same building that contains the inverter and the existing AC grounding electrode, the new grounding electrode conductor from the array may be connected directly to that electrode. A separate electrode will not be required. However, if the connection to an existing electrode requires a horizontal extension at ground level that's greater than 6 feet, a separate electrode is required. This new array-grounding electrode does not have to be bonded to any other electrode.

The module frames must be effectively grounded, and that is not always easy with aluminum frames and copper conductors. The racks must be grounded, and if the PV array is mounted on a metal roof, the roof should also be grounded, since rodent damage and abrasion to the conductors that come in contact with the roof could cause the roof to become energized.

Temperature Corrections

High temperatures can affect both modules and conductors. On a hot summer day, modules can operate under very high temperatures (158°F to 176°F). Exposed wiring can come into contact with hot surfaces, as can conductors that originate in the hot termination boxes attached to the backs of the modules. Because of this, field-installed wiring (and the leads connected directly to the module) must be evaluated for temperature, and ampacity corrections applied.

In most of the United States, a 75°C temperature correction factor is suggested for conductors near PV modules that are mounted roughly 4 inches or less from a surface like a roof.

A cord grip keeps water, critters, and detritus out of a raceway, while allowing the cable to pass through.

An abraded cable (in this case, rodent-damaged) can lead to shorts and malfunctioning systems.

The distance is not exact and is normally measured from the back of the module frame to the surface. However, 4 inches or less is insufficient clearance to allow optimum airflow behind the modules mounted in an array.

If the air space behind the modules is greater than 4 inches, then a 65°C temperature-correction factor is suggested. Again, these are not hard-and-fast numbers, and the individual installation location and microclimate (i.e., Death Valley, California vs. Nome, Alaska) may affect them.

Conductors in conduit exposed to sunlight are also vulnerable to solar heating. *2008 NEC* Section 310.15(B)(2) provides the temperature additions above the expected average high temperatures. These additions apply not only to PV systems but to any conduit run on roofs exposed to sunlight. In many cases, where the high average temperatures are in the 104°F to 113°F (40°C to 45°C) range and the conduit is installed close (1/2 inch or less) to the roof, a 73°C to 78°C correction factor would apply. Those conductors could be delivering energy for 40 years or more, so carefully applying these temperature-correction factors helps ensure that the insulation does not suffer premature degradation.

Access

John Wiles (jwiles@nmsu.edu) works at the Institute for Energy and the Environment, which provides engineering support to the PV industry and a focal point for PV system code issues. A solar pioneer, he lived for 16 years in a stand-alone PV-powered home—permitted and inspected, of course. He now has a 5 kW utility-interactive system with battery backup. This work was supported by the United States Department of Energy under contract DE-FC 36-05-G015149.

Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices by John Wiles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

PV Systems Inspector/Installer Checklist and previous *Code Corner* articles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html


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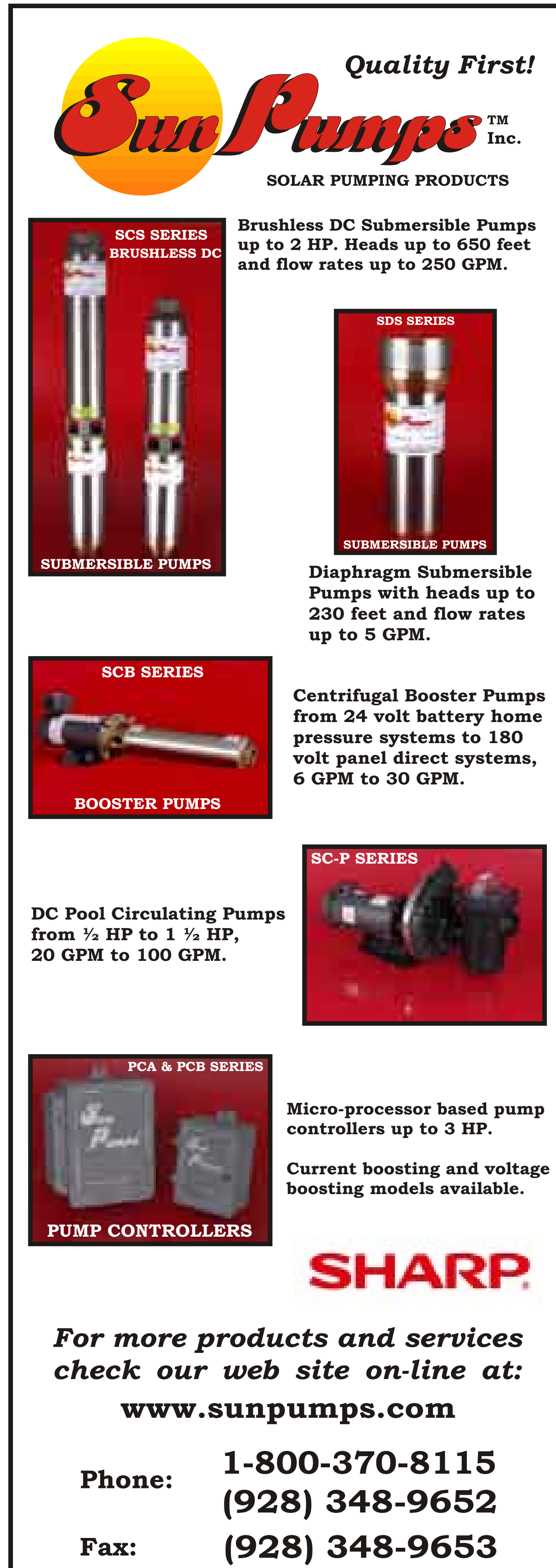
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Smiling Buddha

Nuke Power, "The Bomb" & Closer to Midnight

by Michael Welch

On May 18, 1974, a decade after all nuclear and many non-nuclear states signed the Limited Test Ban Treaty, India exploded its first nuclear bomb in what their government called a "peaceful nuclear explosion," and established the country among nine other "nuclear" states.

Behind the Smiling Buddha

The knowledge, reactor, supplies, and other equipment needed to make the fissionable nuclear materials for the Smiling Buddha, a 12-kiloton bomb, were provided to India under the U.S. "Atoms for Peace" nonproliferation program that was launched in the mid-1950s. Despite the program's required assurances that nuclear technologies would be used only for peaceful purposes and not for military purposes, India developed "the bomb." Since then, India has exploded at least five more nuclear weapons. While the exact numbers are unknown, India likely has a nuclear arsenal of about 60 bombs, and enough refined nuclear materials to make many more.

India also has a very aggressive nuclear-powered electricity program. They have 10 operating nuke plants, with six under construction. Powerful politicians and other leaders are strong promoters of an increased use of nuclear energy, and view it as a necessity for India's development into an international economic power. Others view the push toward nuclear power as weakening India, in that too much capital investment is required. In any case, India's nuclear reactors have been operating far below capacity because nuclear fuel has been difficult to obtain. There is Indian uranium to be mined, but the content in the ore is so low that it is difficult and expensive to extract and process into nuclear fuel.

Normally, a nuclear state like India would have no problem getting uranium for its reactors from other countries. But India has refused to sign the nuclear arms Comprehensive Nuclear Test Ban Treaty and is only one of three countries that has refused to sign the Nuclear Nonproliferation Treaty. It continues to ignore public calls for nuclear disarmament, and refuses to accept International Atomic Energy Agency safeguards. Because of this, the rest of the nuclear world has been refusing to sell uranium and other nuclear materials to India.

A New Deal Dawning

But the nuclear materials restriction has come to an end. Despite India's well-known record for turning nuclear power into nuclear weapons and its refusal to participate in international nuclear controls, the 45-country Nuclear Suppliers Group (NSG) has approved a special exemption from its rules so that nuclear materials can again be supplied to India. The International Atomic Energy Agency (IAEA) also has given their approval.

Ironically, the NSG was originally established as a reaction to India's inappropriate use of nuclear materials, and its stated purpose is to "ensure that nuclear trade for peaceful purposes does not contribute to the proliferation of nuclear weapons or other nuclear explosive devices." It aims to accomplish this "by providing the means whereby obligations to facilitate peaceful nuclear cooperation can

be implemented in a manner consistent with international nuclear nonproliferation norms."

The nuclear industry in the United States and other countries felt like it was missing a big opportunity in India. Indians were building their own reactors—rather than purchasing them from the established nuke industry—but were not able to build more as quickly as they would like. And they were mining their own uranium, rather than getting it from the industry. So efforts by both the Indians and the industry have been underway for years to influence President George W. Bush and Congress to allow nuclear trade with India.

In 2005, Bush and Indian Prime Minister Manmohan Singh announced an agreement intended to generate up to $100 billion in orders for nuclear giants like General Electric and Westinghouse. The agreement with the Bush administration did provide for a few, albeit fairly empty, concessions, including allowing the IAEA to inspect civilian nuclear power plants (not the ones that process weapons-grade nuclear materials) and the promise that India would not use uranium obtained from outside the country to make nuclear weapons (yeah, right).

Just before the end of its 2008 pre-election recess, Congress approved the pact that Bush and Singh worked out so that U.S. nuclear companies could participate in nuclear sales alongside other countries. Having received the green light before, non-U.S. nuclear companies were already clamoring for Indian business. France signed a deal for the nuke company Areva to deliver two reactors to India. Now U.S. nuke producers won't be far behind.

Moving Toward Midnight?

India is not the only nuclear nation that will be affected by this new agreement. Officials in Pakistan are outraged by the plan, since India and Pakistan are hostile to each other. Pakistan is also a nuclear state, and has built and exploded at least one nuclear weapon. The country has two nuclear power reactors and would like to have more. Pakistani leaders decry the favoritism for their enemy that is being shown by the U.S. government and other world powers. But they are concerned about enemies in other parts of the world, as well as the economic development that comes with energy supply, and are hoping that this new U.S.–India pact will set a precedent that will further open up nuclear energy and weapons access for them.

It is chilling that countries with governments even more secretive than our own and countries with poor environmental records and a lack of access to important safeguards are becoming so heavily invested in nuclear energy and weapons. The progressive peace and environmental movements have been so consumed by the Iraq war and human-caused climate issues that this move to reward corporate America at the expense of nuclear dangers and weapons proliferation has barely been a blip on the radar.

Most communities have organizations that are concerned about peace and disarmament issues. Having become focused on Afghanistan, Iraq, Iran, and other wars and hot spots in the world, they may welcome becoming informed on this and related issues. You can find out more about the nuclear power/weapons connections and India/Pakistan issues from Citizens' Nuclear Information Center (http://cnic.jp/english), Beyond Nuclear (www.beyondnuclear.org), and the Bulletin of the Atomic Scientists (www.thebulletin.org).

Courtesy BAS • www.thebulletin.org

Five Minutes 'til Midnight?

Since 1947, the organization Bulletin of the Atomic Scientists (BAS) has used a Doomsday Clock to symbolize figurative midnight, "how close humanity is to catastrophic destruction." Originally used to portray the level of risk from the nuclear arms race, the clock now "encompasses climate change and developments in life sciences that could inflict irreparable harm."

In 1953, the clock showed two minutes 'til midnight, reflecting the design and testing of the hydrogen bomb and the resulting escalation in the arms race. At the height of the U.S./U.S.S.R. Cold War in 1984, the clock read three minutes 'til midnight to represent the enormous nuclear arsenals of both superpowers. After the collapse of the Soviet Union, however, the clock hand retreated to 17 minutes until midnight, under the Strategic Arms Reduction Treaty, which greatly reduced the number of strategic nuclear weapons.

Since then, however, the clock has continued to count down. In January 2007, the hand of the clock was moved from seven to five minutes until midnight, and the clock report read:

> *2007: The world stands at the brink of a second nuclear age. The United States and Russia remain ready to stage a nuclear attack within minutes, North Korea conducts a nuclear test, and many in the international community worry that Iran plans to acquire the Bomb. Climate change also presents a dire challenge to humanity. Damage to ecosystems is already taking place; flooding, destructive storms, increased drought, and polar ice melt are causing loss of life and property.*

The new nuclear agreement with India hasn't yet affected the clock. Only time will tell.

Access

Michael Welch (michael.welch@homepower.com) has been working for a clean, safe, and just energy future since 1978 as a Redwood Alliance volunteer and with *Home Power* magazine since 1990. He looks forward to a world without nuclear weapons and waste—a clean and safe world of peace and sustainability.


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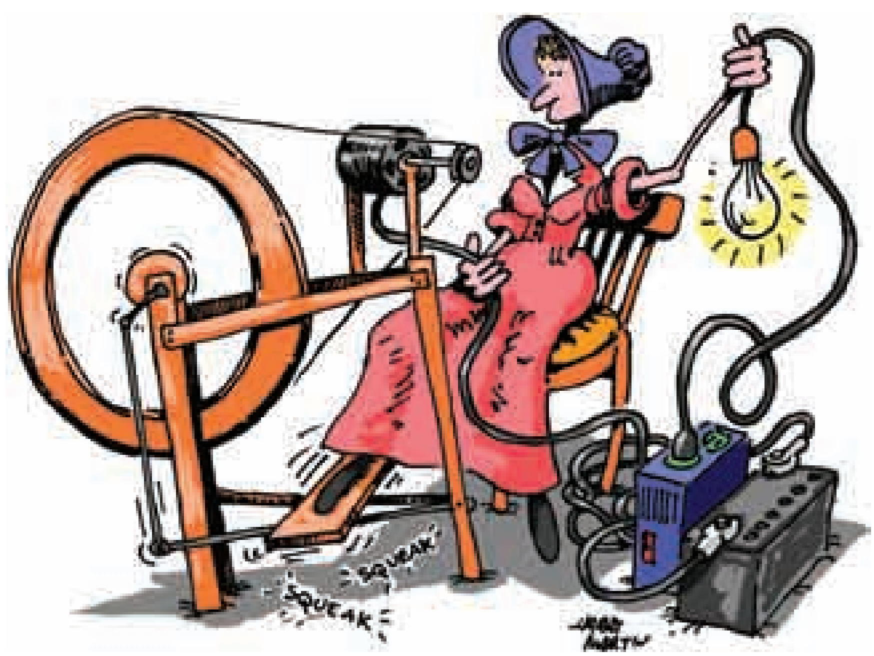
Happy Trails

by Kathleen Jarschke-Schultze



My husband Bob-O and I have been in the renewable energy business for a long time. We have lived exclusively on renewable energy for an even longer time. We, and many of our colleagues from so many years ago, have worked toward the goal of affordable, accessible renewables for all. We still do.

Light in the Forest

People say *Home Power* magazine has changed. Is that ever an understatement! What once was a free, 40-page, black-and-white booklet is now a glossy, four-color, 136-page issue. Publishers Richard and Karen Perez used to gather the crew of "Homies" at our house every two months to assemble the magazine, since we had the biggest living room—and a flush toilet. Using X-Acto knives and gum arabic, we would literally paste up each issue. I can remember cannibalizing earlier issues' pasteboards for ad copy.

At *Home Power*, we would get letters and articles submitted by like-minded enthusiasts saying, "Wow, look what I did—and it works!" In the early days when renewables were in their infancy, RE pioneers eagerly shared the knowledge that would shed a little more light onto the trail. These days, the articles tend to be more, "Hey, look what we can do now!"

It's always reminded me of how airplane piloting began. Got enough money for a plane? Sure. Well, here's the throttle and there's the brake, and when you pull back on that lever, it'll point the nose up. Seat-of-your-pants flying. Pioneering a technology.

The Tribe

In those days, everyone in the biz knew each other on a first-name basis—at least out here on the West Coast. We were passionate about our message and irreverent in our humor. This has evolved, also. I'd venture to say you're not going to see a Lil' Nukie ad in the April Fool's issue of *Home Power* again.

At the last Solar Energy Expo and Rally in Willits, California, in the early 1990s, a bunch of us were hanging around the *Home Power* tent after the public had left. To give you an idea of how grassroots the event really was, the security guy had given me a key to the gate so I could let people out and lock up when we left.

So there we were, telling stories about what had happened and who we had met that day and such. Bob-O's name came up for discussion—like when, where, and why he had come by his moniker. Then Larry Schlussler from Sun Frost told us he had always thought his name was too long. Lar-ry. Two syllables, when he just wanted one. That night he was unanimously dubbed "Ed."

I called Sun Frost a while back and jokingly asked for "Ed." Some other guy really named Ed came to the phone. While Bob-O and I still call Larry "Ed," I guess you had to be there that night many years ago to appreciate or even get the joke.

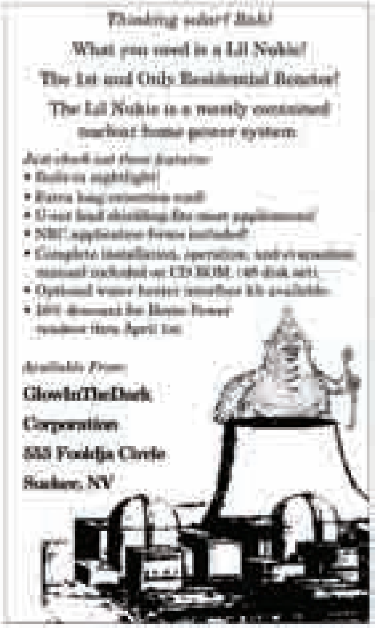
Sentimental Journey

I've realized that *we* off-gridders are the old timers. Back in the day, 12-volt electricity ran our lights, ham radio, radio telephone, and cassette tape player. Although we did not spend the money to buy expensive 12 V appliances, I can tell you from personal experience that 12 V incandescent lightbulbs are never on sale—never.

We used to run our whole house and biz on a 1,300-watt, modified sine wave PowerStar inverter. But we soon found out that some electronic brains don't run on square (modified) sine waves. Back then, purchasing appliances and even computer gear "off the rack" was difficult and even dicey. The worst was when something would work for a day and then quit.

Our next inverter was a Trace SW4024, No. 35 off the line. It was big, beautiful, full sine wave, and took us to a whole new level of energy production. This also opened the door for a better selection of appliances. Since the demise of Trace Engineering, we've moved on to an OutBack system—yet another big improvement on power quality.

Way back when, we had four 48-watt Kyocera modules on a ground mount made of wood and steel angle. Every solstice and every equinox, we would adjust the array's



Surprise! Lil' Nukie makes another appearance.

tilt to maximize its production. Today, we have 2,195 W of PV capacity on Array Tech dual-axis trackers, and we're planning to install more this year. Bob-O says there are two kinds of people who want PV: Those who don't yet have it and those who want more.

Growing with Change

Over the past 30 years, products, technology, marketing, and the players involved have all changed—grown in size—here in the United States and globally. Many more people are using RE now. Isn't that what we wanted? Hell, yeah! Nothing is improved by staying the same. Change is growth; growth is change.

Today, I marvel at all of the right-out-of-the-gate, spiffy grid-tied systems in *Home Power*. High-fashion renewables, and the people who have them aren't running into a skunk by their compost bin, like I did two days ago. They haven't walked over a rattlesnake in their greenhouse and *then* noticed it on their way out. These folks are not the renewable pioneers, but the settlers. As our friend Bob-1 (Bob Maynard) says, "The pioneers cut the trails, the settlers get the land." So it goes.

I'm not grousing—I'm just making a distinction. This is what we are still working toward, old and new advocates together. More RE is used every day. With the global realization of human-caused climate change, the whole renewable scene is going to keep growing, and has to keep growing. This is what we wanted.

RE Boulevard

Alas, we are no longer free to be the wild and crazy, irreverent solar bozos we once were. I am reminded of Richard Perez's comment on page 10 of *HP13*: "Recently arrived citizen Dana Flett doesn't know solar from shinola, but she's living in a better world because her folks give a damn." Dana is now in her first year attending U.C. Berkeley.

Only through conformity have we been able to move forward with the rest of the renewables movement. Bob-O even teaches the *National Electrical Code* in his workshops these days. Who knew? I miss the fun we bozos used to have. Oh, I still see the humor in my day-to-day life. I just wonder if other people see it, not having the back-story.

Nowadays it is a great enjoyment when any of the pioneers meet. Usually at least a handful of us silverbacks will be at any given energy fair, trade show, or RE education class. The feeling of camaraderie is deep. We set out to cut a trail. Now that trail is a thoroughfare, soon to be a highway. We talk about the old days, but more often than not, the conversation is about the future. The brightly lit, renewable future, ahead of us all.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is keeping the home fire burning at her off-grid home in northernmost California.

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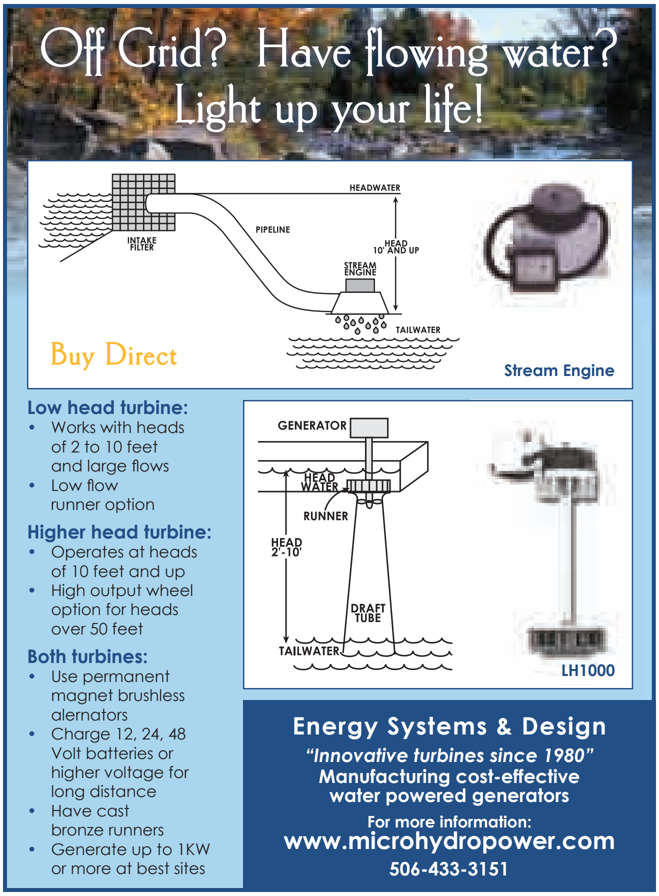
17. I certify that the statements made by me above are true and complete. Scott M. Russell, Operations Director, 9/26/08.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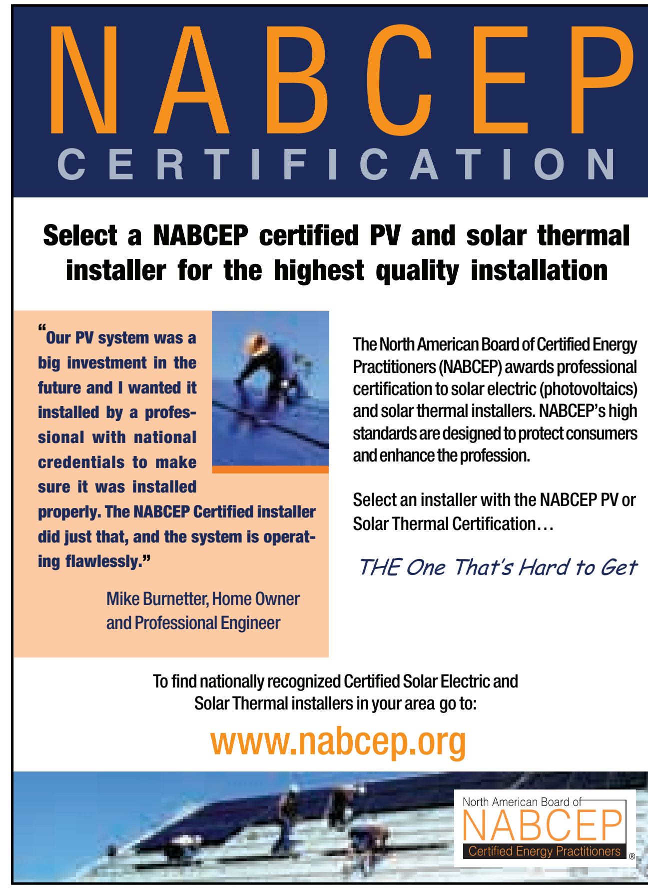
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Arcata, CA. Workshops & presentations on RE & sustainable living. Campus Center for Appropriate Technology • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

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COLORADO

Carbondale, CO. Workshops & online courses on PV, water pumping, wind, microhydro, solar hot water, alternative fuels, green building & more. Solar Energy Intl. • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. fleslie@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

IOWA

Iowa City, IA. Iowa RE Assoc. meetings. 319-341-4372 • irenew@irenew.org • www.irenew.org

MASSACHUSETTS

Mar. 10–12, '09. Boston. BuildingEnergy09. Workshops & sessions by 150 experts on climate change, high-performance buildings, large-scale RE, net-zero energy & more. www.buildingenergy.nesea.org

Auburn, MA. Seminars: Solar Basics, PV, Hot Water, Wind, RE & more. CNE Solar Store • 508-832-4344 • peter@cnesolarstore.com • www.cnesolarstore.com

Hudson, MA. Workshops: Intro to PV; Advanced PV; RE Basics; Solar Hot Water & more. The Alternative Energy Store • 877-878-4060 • support@altenergystore.com • http://workshops.altenergystore.com

MICHIGAN

West Branch, MI. Intro to Solar, Wind & Hydro. 1st Fri. each month. System design & layout for homes or cabins. 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

MISSOURI

New Bloomfield, MO. Workshops, monthly energy fairs & other events. Missouri Renewable Energy • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV, more. Sage Mt. Center • 406-494-9875 • www.sagemountain.org

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Rumney, NH. Green building workshops. D Acres • 603-786-2366 • info@dacres.org • www.dacres.org

NEW MEXICO

Six NMSEA regional chapters meet monthly, with speakers. NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NORTH CAROLINA

Saxapahaw, NC. Solar-Powered Home workshop. Solar Village Inst. • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OREGON

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Philadelphia Solar Energy Assoc. meetings. 610-667-0412 • rose-bryant@verizon.net • www.phillysolar.org

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Summertown, TN. Workshops on PV, alternative fuels, green building & more. The Farm • 931-964-4474 • ecovillage@thefarm.org • www.thefarm.org

TEXAS

Jan. 21–22, '09. Austin. Wind Energy Institute. Technological, business & legal info on wind development. Univ. of Texas School of Law • 512-475-6700 • service@utcle.org • www.utcle.org

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

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WASHINGTON STATE

Guemes Island, WA. SEI '09 workshops. Apr. 6–11: Wind-Electric Systems Maintenance & Repair; Apr. 13–18: Homebuilt Wind Generators. See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

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Custer, WI. MREA '08–'09 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Wind Site Assessor Training & more. 715-592-6595 • info@the-mrea.org • www.the-mrea.org

Amherst, WI. Artha '08–'09 workshops: Intro to Solar Water & Space Heating Systems; Installing a Solar Water Heating System; Living Sustainably & more. 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

COSTA RICA

Jan. 1–9, '09. Mastatal. Solar Electricity for the Developing World. Hands-on workshop. See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

Jan. 31–Feb. 9, '09. Durika. RE for the Developing World. Hands-on workshop. See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

JAMAICA

Jan. 12–16, '09. Mayfield. Intro to PV & Solar Cooking. A hands-on workshop. 970-921-5529 • hareef99@yahoo.com • solarenergyclasses.com

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Jan. 5–15, '09. Totogalpa. Solar Cultural Course. Lectures, field experience & ecotourism. Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

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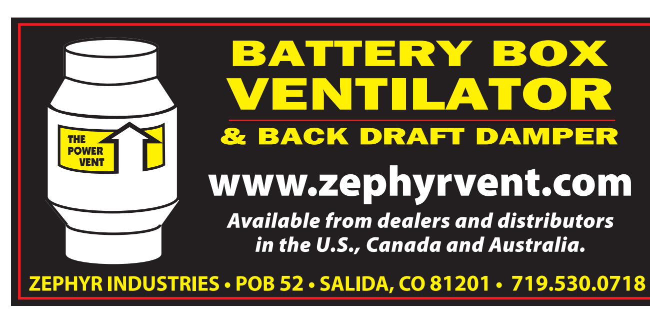
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PV Array Temperature Impact Calculations

Temperature affects a PV module's voltage, and must be considered when matching a PV array to either a maximum power-point tracking (MPPT) charge controller (for battery-based PV systems), or a batteryless grid-tied inverter.

Charge controllers and inverters have a DC-input operating range that the array must stay within. If the DC input dips below the minimum voltage, the system may go off-line and no power will be produced. If the DC input maximum voltage is exceeded, damage to the charge controller or inverter can occur, or potential production will be lost.

To calculate an array's voltage range, you must first determine the record low and the average high temperatures for the site. These temperatures for a weather station near you can be found by appending your zip code to the end of this Web address: www.weather.com/weather/climatology/monthly/.

Using that data, you can find the highest open-circuit voltage (Voc) and lowest maximum power voltage (Vmp) for a given array—for example, a single-string, 10-module, grid-tied array installed in Paonia, Colorado (zip code 81428).

Here, the record low is -31°F (-35°C) and the highest average high temperature is 90°F (32°C). Checking the back of the modules, each is specified at:

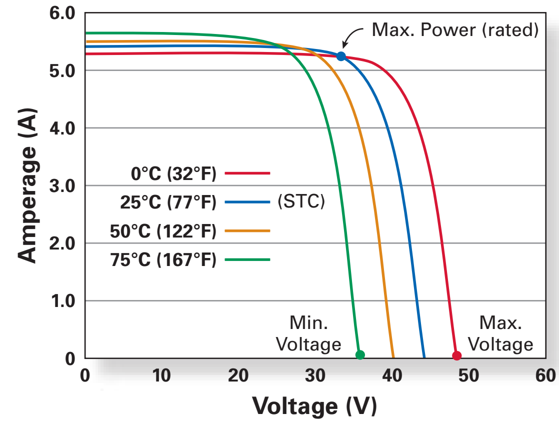
Voc: 44.0 VDC
Vmp: 35.7 VDC
Temperature coefficient of Voc: -160 mV/°C or -0.160 V/°C

Cold = High Voltage

The maximum array Voc considers that the site's coldest temperature is usually reached close to dawn. With little or no sun exposure, the PV cells are assumed to be at ambient air temperature.

Online Temperature Data

PV Temperature Performance



1. Calculate the difference between the low temperature and standard test conditions temperature of 25°C: **-35°C – 25°C = -60°C**
2. Use the temperature coefficient to find the change in Voc per module: **-60°C x -0.160 V/°C = 9.6 V**
3. Adjust the module Voc and multiply by the number of modules in series to get the maximum array Voc: **(44.0 V + 9.6 V) x 10 modules = 536 V**

Hot = Low Voltage

To find the lowest Vmp (to which the voltage will drop when the modules are hottest), assume the sun has heated the cells to 30°C higher than ambient air temperature (at irradiance = 1,000 W/m^2).

1. Calculate the cell temperature at the site's highest ambient air temperature of 32°C: **32°C + 30°C = 62°C**
2. Calculate the difference between the high cell temperature and STC conditions: **62°C – 25°C = 37°C**
3. Use the temperature coefficient to find the change in Vmp: **37°C x -0.160 V/°C = -5.92 V**
4. Adjust the module Vmp and multiply by the number of modules in series to get the minimum array Vmp: **(35.7 V + -5.92 V) x 10 modules = 298 V**

Solution

For this example array, an inverter would need to accommodate a DC input range of 298 V to 536 V.

—Justine Sanchez

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